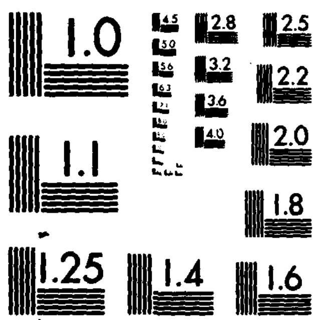
AD-A091 854 RCA AUTOMATED SYSTEMS DIV BURLINGTON MA F/G 14/2
MANUFACTURING METHODS AND TECHNOLOGY PROGRAM AUTOMATIC IN-PROCE--ETC(U)
OCT 80 R J WILDENBERGER, J M LASKEY DAAB07-77-C-0585
UNCLASSIFIED DELET-TR-77-0585-F NL

1 of 2



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

K LEVEL III

F056 579

(7)

Research and Development Technical Report
DELET-TR-77-0585-F

AD A091854

Manufacturing Methods and Technology Program Automatic In-Process Microcircuit Evaluation

J. M. Laskey
R. J. Wildenberger

RCA|Government Systems Division
Automated Systems
Burlington, MA 01803

OCTOBER 1980
Final Report for Period
22 September 1977 - 15 August 1980

Approved for Public Release; Distribution Unlimited

Prepared for:
Electronics Technology & Devices Laboratory

ERADCOM
US ARMY ELECTRONICS RESEARCH AND DEVELOPMENT COMMAND
FORT MONMOUTH, NEW JERSEY 07703

80 11 17 139

NOTICES

Disclaimers

Disposition

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER DELET-TR-77-0585-F	2. GOVT ACCESSION NO. AD-A091
3. RECIPIENT'S CATALOG NUMBER 854	
4. TITLE (and Subtitle) Manufacturing Methods and Technology Program Automatic In-Process Microcircuit Evaluation	5. TYPE OF REPORT & PERIOD COVERED Final Report 22 September 1977-15 August 1980
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Wildenberger, R. J., Laskey, J. M.	8. CONTRACT OR GRANT NUMBER(s) DAAB07-77-C-0585
9. PERFORMING ORGANIZATION NAME AND ADDRESS RCA/Government Systems Division Automated Systems Burlington, Massachusetts 01803	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 2779808
11. CONTROLLING OFFICE NAME AND ADDRESS FRADCOM DELET-IA-T Fort Monmouth, New Jersey 07703	12. REPORT DATE October 1980
	13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) R. J. Wildenberger J. M. Laskey	15. SECURITY CLASS. (of this report) Unclassified 175
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

AIME (Automatic In-Process Microcircuit Evaluation), Hybrid, Inspection, Automated Inspection, RBV (Return-Beam-Vidicon), Image Processing.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This final report summarizes all the work performed under the subject contract. The method of approach to the program included system analyses to investigate techniques for hybrid image extraction, determination of illumination requirements and techniques, and determination of Return Beam Vidicon operating modes for the demonstration model. An AIME demonstration model and system software were designed, built, integrated and tested. Technical and physical descriptions of the demonstration model equipment/software design and configuration are provided. (Cont.)

DD FORM 1473, 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

40

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

20.(Cont.)

Analysis was made of typical characteristics of hybrid thick-film substrate conductor faults resulting from printing, probing and work-in-process handling. Based on this analysis test sample substrates containing designed-in-faults were designed, fabricated and used to evaluate AIME demonstration model operation.

Data resulting from AIME operation, utilizing the test sample substrates, demonstrated automatic detection of 96.4 percent of all substrate defects. When defects were classified by size, AIME successfully detected 100 percent of defects three (3) mils or larger, and 81 percent of defects less than three (3) mils. Evaluation was also made of a semi-automatic mode of operation for pre-cap hybrid visual inspection.

Recommendations for further system development are included.

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

NOTICES

Disclaimers

The citation of trade names and names of manufacturers in this report is not to be construed as official Government indorsement or approval of commercial products or services referenced herein.

Disposition

Destroy this report when it is no longer needed. Do not return it to the originator.

NOTICE

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

This project has been accomplished as part of the U.S. Army Manufacturing Methods and Technology Program, which has its objective the timely establishment of manufacturing processes, techniques or equipment to insure the efficient production of current or future defense programs.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont.)

TABLE OF CONTENTS (Cont.)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Cont.)

LIST OF TABLES

PURPOSE

The purpose of this program is to establish a Manufacturing Methods and Technology Program (MM&T) in accordance with Step 1, paragraph 1.2.2.1, of Electronics Command Industrial Preparedness Procurement Requirements (ECIPPR) No. 15, dated August 1976, for Automatic In-Process Microcircuit Evaluation (AIME), which will establish techniques for the automatic inspection of thick-film conductor lines on substrates and the elimination of microscopes for visual pre-cap inspection of hybrid assemblies for use in Army electronic equipments. The MM&T program will include:

(1) System analysis to investigate hybrid image extraction techniques, illumination techniques, and RBV operating modes so that the basis for the AIME configuration can be established.

(2) Design of the AIME Demonstration Model, system software, and test program.

(3) Fabrication of the Demonstration Model Design. The system will contain all the necessary elements required to acquire test data on the inspection of substrate and hybrid assemblies to establish the basis for development of an AIME Equipment configuration and specifications for future procurement. The system elements performed the following functions

- Control of the AIME system
- Test program generation
- Stimulus and measurement, as required.

The AIME system will be demonstrated using a specially designed test pattern substrate and a typical hybrid assembly. Software will be developed to provide the control and evaluation required for the inspection of the test pattern substrate and hybrid.

In addition, an English Language Test Document (ELTD) will be generated for the inspection of the specially designed substrate and the hybrid assembly.

(4) A data package for the Demonstration Model will be provided including Test and Demonstration Report, Instruction Manual, Engineering Drawings, equipment specification, program listings, and ELTDs for the substrate and hybrid inspections.

(5) An AIME Production Capability Demonstration for Government and industry was successfully conducted.

This MM&T program was the result of work done on the Automated Image Device Evaluator (AIDE) Program, Contract DAAB05-74-C-2524. The purpose of the AIDE program was to provide the basis for automated inspection of second generation image intensifier tubes. This program utilized AIDE hardware components in the design and fabrication of the AIME Demonstration Model.

GLOSSARY

AIDE	Automated Image Device Evaluator
AIME	Automatic In-Process Microcircuit Evaluation
ARTS	AIME Run-Time System
CLI	Command Line Interpreter
CPU	Central Processing Unit
DMA	Direct Memory Access
I/O	Input/Output
MAP	Memory Allocation and Protection
RBV	Return Beam Vidicon
RDOS	Real-Time Disc Operating System
TBC	Time-Base Corrector
RTS	Run Time System
TVL	TV Line
UUT	Unit Under Test

SECTION 1
SYSTEM DESCRIPTION

1.1 TECHNICAL DESCRIPTION

1.1.1 General

Background

The Automated In-Process Microcircuit Evaluation (AIME) System will provide the basis for establishing test techniques for the automatic inspection of thick-film conductor-lines on substrates, and eliminates the need of microscopes for visual pre-cap inspection of hybrid assemblies.

There are many points, during the manufacture of hybrid microcircuits, at which some degree of visual inspection is made. However, there are specific major points at which 100 percent visual inspection is made. These inspection points are:

(1) After thick-film processing of the substrate is complete (before the start of assembly).

(2) Immediately before sealing the assembled hybrid package (pre-cap visual).

There are additional significant points, during the thick-film processing of ceramic substrates, where 100 percent continuous inspection would be very desirable, but the costs of manual inspection are prohibitively high and the inspection process itself impedes the achievement of desired throughput rates for printing, drying, and firing. A viable system of automatic in-process inspection among the operations involved in adding a thick-film layer to the substrate lot, would greatly improve the yields and assure a more dependable end product.

Figure 1-1 shows a simplified process flow drawing for the manufacture of thick-film hybrids from the point of cleaning the alumina substrates to the point after assembly where the hybrid circuit is hermetically sealed. This process flow drawing is arranged to highlight those visual inspection points located in three major areas of the process sequence.

At process point 1A, immediately after printing, a rejected substrate can readily be washed off with a suitable solvent. If the flaw was caused by a problem in the printing process (such as a clogged screen), corrective measures could be taken before too many of the bad prints were made.

At the drying or baking process point, 1B, certain trapped particles, such as lint and dust, could be detected. If flaws are detected at this point, the dried material can be removed from the substrate (more vigorous cleaning is required). Again, as in the case of the substrates with set ink, the plates are recovered and the value added to the substrates in earlier steps is not lost.

Inspection at point 1C occurs after each successive printed layer is fired. The value of picking up faults at this point is to avoid any further labor on a defective substrate, take corrective action as appropriate on any possible out of control process and perform any acceptable, cost-effective rework to the rejected substrates.

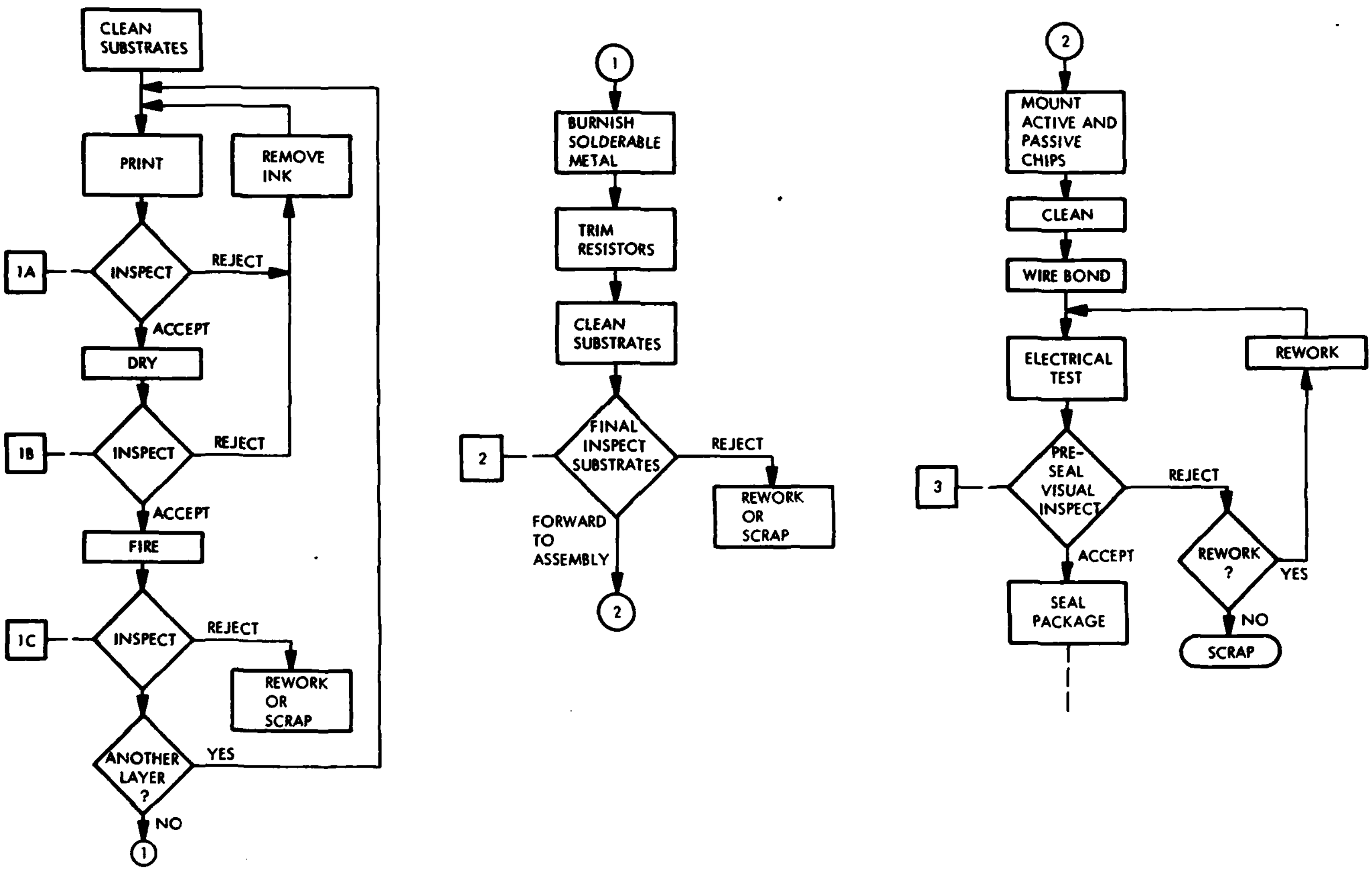


Figure 1-1. Manufacturing Process Flow with Inspection Points

Inspection point 2 on the process flow drawing, identifies the last action to be performed on a substrate before forwarding it to the assembly operations where chip parts are attached and where semiconductors are connected by wiring bonds to the substrate metalization. As previously mentioned, this is a 100 percent inspection point. Automatic inspection on an in-process basis should make this pre-assembly inspection far less important. An interactive inspection system would provide the operator with the ability to identify marginal situations. After electronically zooming in on the area of interest the display on a large screen video monitor would allow the operator to inspect the suspicious area in detail.

At process inspection point 3 (pre-cap visual inspection) a 100 percent inspection is also routinely made of the completed hybrid assembly. At this inspection point the inspection system could be preprogrammed to a disciplined sequence of displayed substrate areas to make sure that the visual inspection is thorough and looks closely at any specific area that is particularly vulnerable to flaws in the manufacture.

System Components

Figure 1-2 is a simplified block diagram of the AIME Demonstration Model. The basic components of the system are:

(1) Control/Display Station

- Computer and Peripherals
- Video Processor and I/O Control
- RBV Electronics, Power Supply
- Sync Generator
- Time-Base Corrector
- Video-Disc Recorder/Reproducer
- Video Monitor
- Illumination Power Supplies

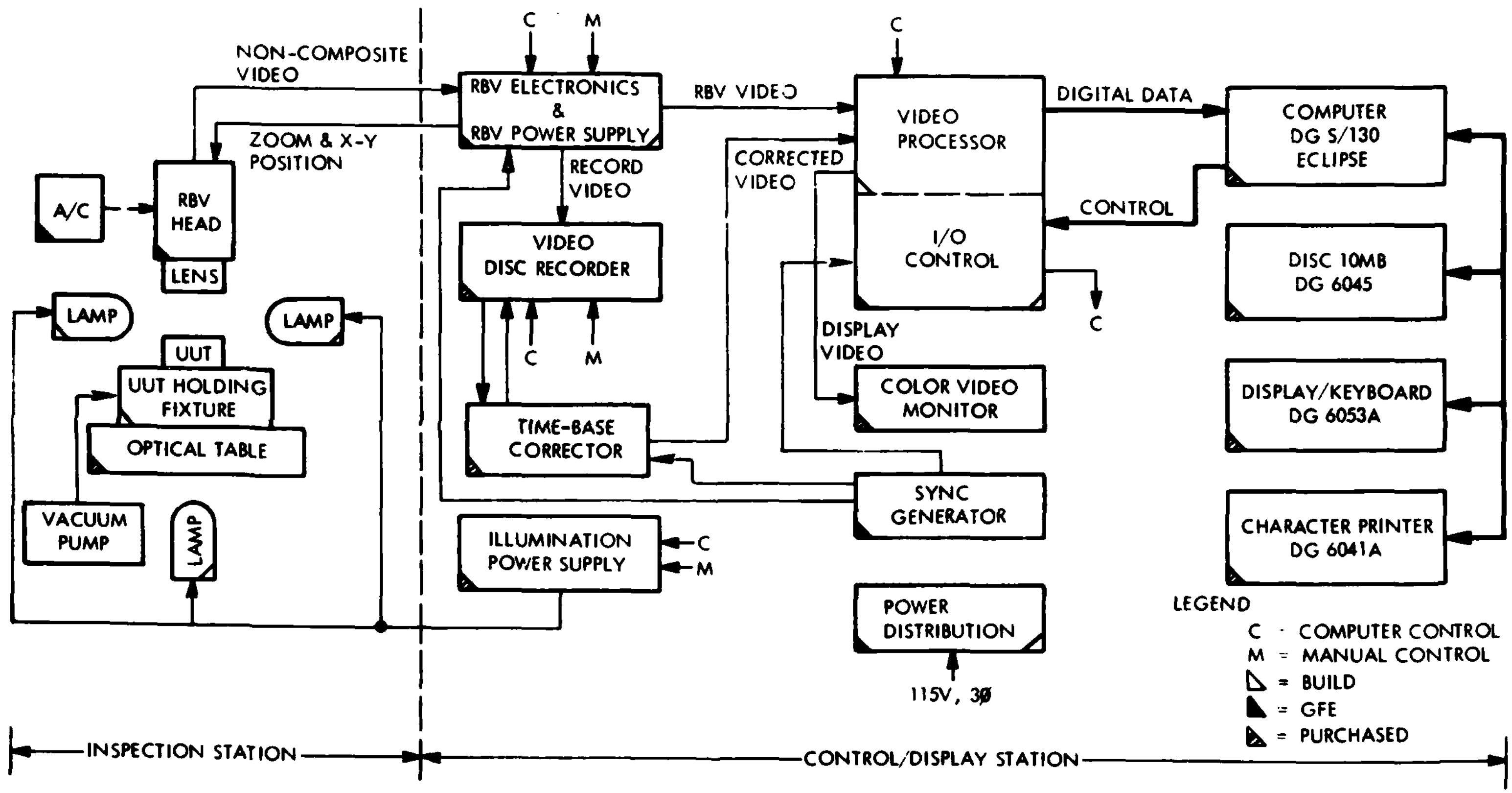


Figure 1-2. AIME Demonstration Model - Block Diagram

(2) Inspection Station

- RBV Camera Head with Lens
- Illuminators (Lamps)
- UUT Holding Fixture
- Optical Table with the Structure/Shroud Assembly
- Air Conditioner Unit

The legend, in Figure 1-2, identifies those items which are under computer control and/or manual control. Further, the legend also shows which of the components were designed and built (new designs), purchased (modifications as necessary), and Government Furnished Equipment - GFE (modified as necessary). All GFE items are removed from the AIDE system (Contract DAAB05-74-C-2524).

Operation

The following is a general description of a typical substrate inspection process performed by the AIME system. The UUT is placed in the holding fixture and subsequently illuminated, projecting the UUT image on the RBV face. The AIME Control selects and positions the RBV scan, via the RBV electronics, to the desired UUT image area to be viewed. The RBV output is a video signal which is directed to the RBV electronics and then to the video processor. A pre-recorded image of the same UUT area is obtained from the video disc-recorder and directed to the video processor.

The video processor performs two functions. First, the difference between the RBV video signal and the video disc-recorder signal output is taken, digitized and fed into the core memory of the AIME system computer. Second, the processor takes the same difference video signal and combines it with the RBV video signal which is then displayed on the color video monitor.

The combination of the difference and RBV video signals is such that the RBV output appears as a black and white image on the monitor. The difference video is directed to the red and green gun-driver circuits. Thus, if the RBV image is wider than the recorded image the green color-gun output will be increased resulting in a highlighting of the greater than normal UUT area. A similar result is obtained if the UUT image is narrower than the recorded image, except now the red color-gun output is increased.

When the inspection is complete the AIME control repositions the RBV beam scan to the next UUT area to be inspected, and repeats the above process until the UUT inspection is completed.

The hybrid-assembly inspection is similar to that described above for the substrate inspection, except that the video disc-recorder is not used and the color highlighting of an out-of-tolerance area is not generated.

1.1.2 Control/Display Station

The major elements of the Control/Display Station are shown in Figure 1-2. One of the two major functions performed by this station is control of the AIME operating modes. This control is maintained by the computer and associated peripherals. Table 1-1 identifies the selected models and key features of these items.

The remaining elements of the Control/Display station are associated with the RBV and Video Processor. Among these items are certain units which are purchased from selected vendors. These items include the video disc-recorder, sync-generator, time-base corrector, color video monitor, and illumination power supplies. These items are also in Table 1-1.

The two methods of controlling the AIME system are with the computer and associated interface (CPU control), and with controls located on the front panels of the RBV electronics chassis, the video processor chassis, and the video-disc recorder (Local Control).

Table 1-1. Control/Display Station Elements

Device	Model	Features
Computer	ECLIPSE Data General (DG)	64K words, memory allocation and protection (MAP), 700 nsec memory cycle
Disc Subsystem	6045 (DG)	10 megabyte storage, removeable disc-pack unit
Display/Keyboard	6053A (DG)	Detachable keyboard, 96 ASCII character set, 5 x 7 dot matrix, 1920 character storage, user-defined keys
Printer	Dasher 6041A (DG)	60 cps, 40 character buffer memory
Video Disc Recorder	VDR-1RA ARVIN-ECHO	400 frame storage, variable frame step-rate, remote control
Time Base Corrector	DPS-1 Digital Video Systems	Will correct greater than 2 μsec of jitter to better than 10 nsec
Color Video Monitor	5411RS19 Conrac	High resolution color monitor
Illumination Power Supplies	6329 Oriel	Stabilized power supply for Quartz Halogen Illuminators
Sync Generator	Tektronix 1410	Provides horizontal and vertical drives as well as Composite Sync and Blanking signals

When the AIME system is being operated by the front panel controls, the computer does not influence the system operation.

1.1.2.1 CPU Control Mode

Under CPU Control, all elements of the AIME System are operated by computer generated commands with operator interventions as required. The primary computer/operator interface is the display/keyboard. The color video monitor is a secondary interface element.

Three basic operating modes are possible under CPU Control. These are:

- Manual Inspection
- Semi-Automatic Inspection
- Automatic Inspection (Demonstration System).

The Manual Inspection operating mode allows the operator to select the desired RBV scan position, zoom-ratio, illumination, as well as the color video monitor display. The operator controls these parameters by 1) depressing the appropriate key on the keyboard, 2) observing on the computer interface display that his selection was accepted and executed by the computer, 3) verifying on the video color monitor that he has the correct view. The operator may then modify the present monitor image or continue with the Manual Inspection.

In addition to the Manual Inspection just described, the operator may also create an inspection program by entering the Program Generation option of the Manual Inspection Mode. With this option, the operator may select the desired monitor view and then depress a keyboard button which will then generate the AIME computer commands required to duplicate the view being observed. Thus, an Inspection Program may be generated by the operator, without any prior knowledge of the AIME System language.

Figure 1-10 shows the keyboard layout with the associated AIME System commands.

The Semi-Automatic Inspection mode is utilized after an inspection program has been generated. In this mode the computer sequences through the predetermined inspection steps, presenting on the monitor a view for the operator to inspect the substrate or hybrid. The operator evaluates each substrate and presses the appropriate (pass or fail) button on the keyboard. The computer does not evaluate the video signal except as the operator indicates by his keyboard entered response.

The Automatic Inspection Mode for the AIME Demonstration System will, under computer control, set up the RBV camera operating mode, select the correct stored image on the video disc recorder, input and evaluate the video difference data, and continue the inspection process until a fault is found or the substrate inspection has been completed.

Essential for implementing the CPU control mode, is an interface board within the S/130 computer. This board, referred to as the 4ø4ø board, contains circuitry which performs two functions: 1) Transfer of digital words to the AIME system which are used to control the AIME system elements. 2) High-Speed transfer of digital words, which represent the video image, into the computer core memory. This board communicates with the AIME system via a bi-directional data-bus routed to the IO circuitry, located in the IO processor chassis (paragraph 1.1.2.4).

Careful partitioning of the high-speed or DMA circuitry, allows for the use of a minimum of data and control lines between the computer and the IO circuits. A total of twenty-seven differential lines make up the AIME computer interface. A discussion of the computer interface is given in paragraph 1.1.2.4.

1.1.2.2 Local Control Mode

The LOCAL control mode is intended as a setup, diagnostic, or evaluation aid. It is not intended for use by an unskilled operator.

This control mode allows the AIME system to be operated in a manner similar to that of the CPU mode. The distinguishing difference between the two control modes is that the computer control is completely removed from the system. Instead, control of the AIME system components is accomplished by controls on the front panels of each of the following components: the RBV electronics chassis, the IO processor chassis, and the video disc recorder.

The details of these front panel controls are given in the descriptions which follow.

1.1.2.3 Power Distribution

AIME power distribution is centralized in one chassis. This chassis contains all the required circuit breakers for controlling the main power to the RBV electronics, the illumination power supplies, computer and the associated peripherals, video devices, the I/O processor chassis and the air conditioner/vacuum pump.

1.1.2.4 IO Processor Chassis

The IO processor chassis contains three main elements: the IO circuitry, the video processor digital, and the video processor analog circuits. This chassis has four low-voltage power supplies which provide +5, -5, +24, and $\pm$ 15 volts DC. The CPU control structure is illustrated in Figure 1-3.

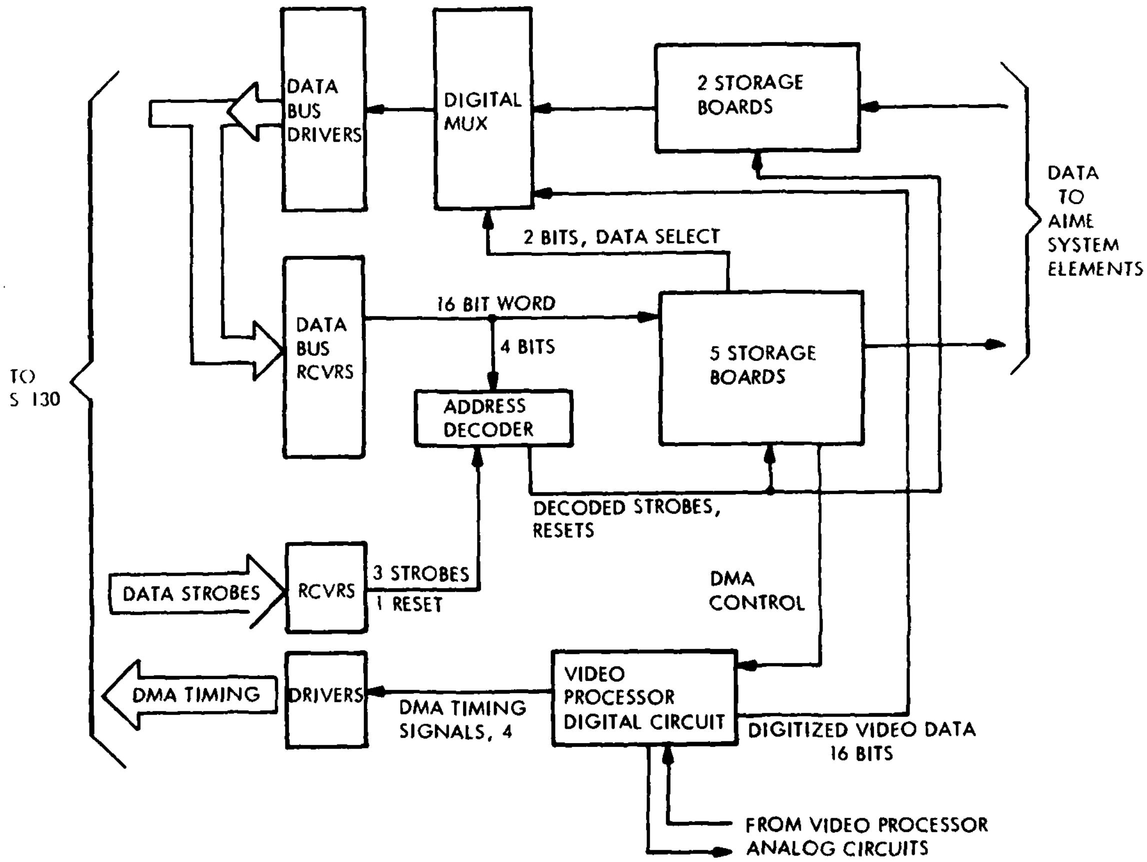


Figure 1-3. AIME CPU Control Structure

1.1.2.4.1 IO Circuits

These circuits provide the main link between the computer and the AIME system. Data-bus receivers and drivers provide the actual data link as well as sending system timing signals to the computer. An address decoder and seven storage cards provide the means by which the CPU Mode of control is implemented.

Data from the computer is presented on the data-bus and detected by the receivers as shown in Figure 1-3. A strobe pulse is used to capture the data. Sending data to the IO circuits is a two-step process:

1) The data-bus direction is set to "output" while placing on the data-bus a 16-bit word. Four of the bits are used to select the desired storage board. A strobe pulse latches the 4-bits in the address decoder.

2) A second 16-bit word, representing the computer command word, is then sent along with another strobe pulse. The strobe pulse is routed through the address decoder to the "addressed" storage board. The data-bus direction is returned to "input". (For speed considerations the normal state of the data-bus is the "input" state).

The storage cards are wired to the appropriate AIME system element. Inputting data from the AIME system is a three-step process.

1&2) Using the "output" sequence described above, the AIME element to be read is selected by routing the data through a digital multiplexer to the data-bus

drivers. A two bit code is used to select the data.

3) With the data-bus in the "input" state the routed data is strobed into the computer.

1.1.2.4.2 Video Processor Digital Circuits

The video processor digital circuits generate all the functions to provide the high-speed data transfers from the AIME system into the Computer Memory. In addition, these circuits generate the system timing signals required by the computer. Figure 1-4 shows the video processor digital circuits in the CPU control structure.

The video processor digital circuits perform two main functions:

1) Convert the serial digitized video data into parallel 16 bit digital words.

2) Generate the timing signals required to perform the DMA data transfers.

As depicted in Figure 1-4, these circuits require signals from the system sync generator and the TBC. The sync generator provides the first-field, vertical drive, horizontal drive, and composite blanking signals while the TBC is the source of a 14.3 MHz clock signal. The serial video data is obtained from the video processor analog circuits.

1.2.4.3 AIME Video Processor Analog Circuits

The video processor analog circuits provide the following functions:

(1) Display switching

(2) Differencing of live and playback video

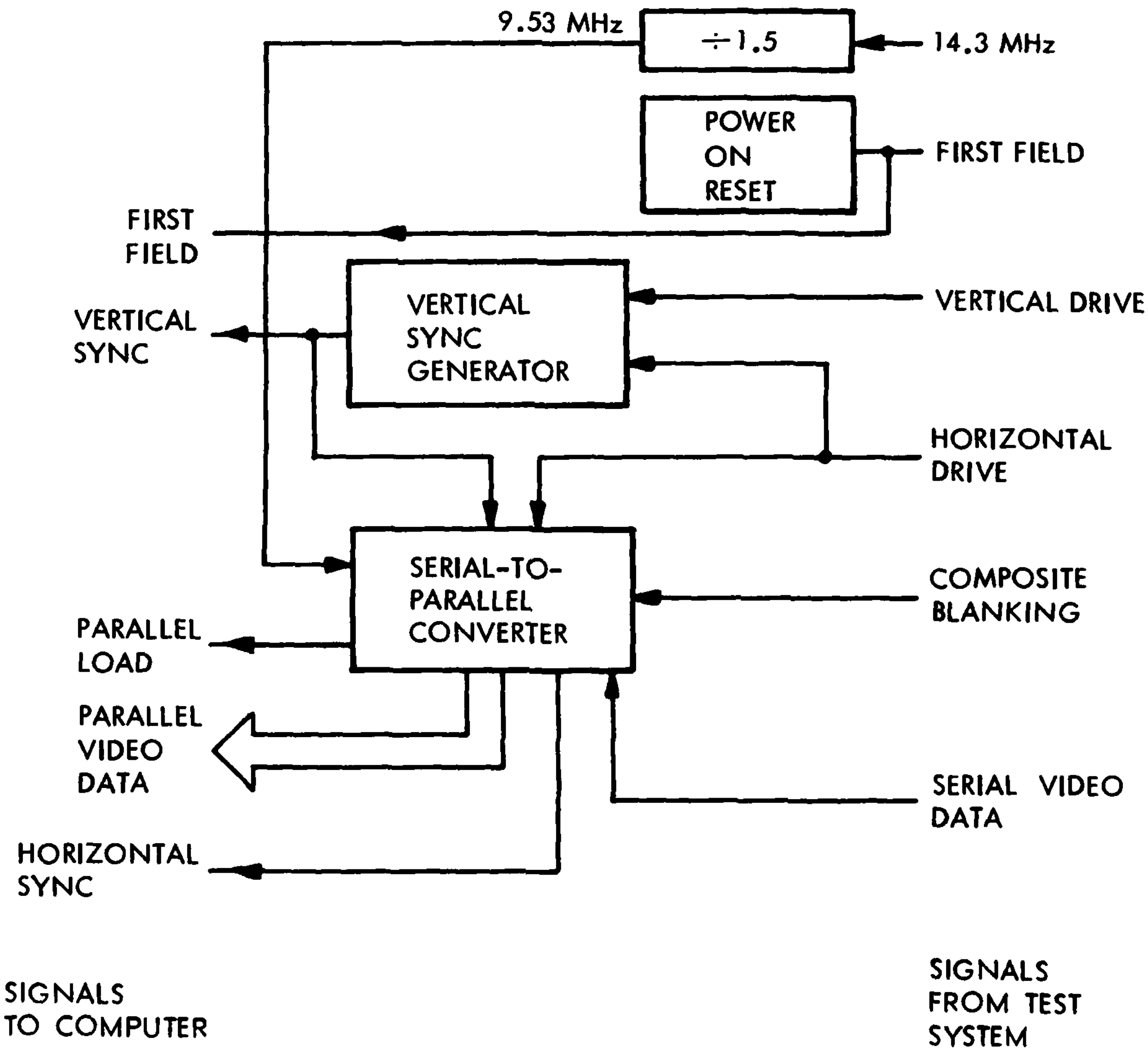


Figure 1-4. Video Processor Digital Circuits Block Diagram

(3) Display color enhancement

The video processor, fabricated in a single copper clad board, is housed within a separate package.

Display switching is performed by relays on the video processor board. These relays function either under CPU control or under the control of a rotary display select switch on the I/O Processor front panel when the system is in the Local Operate or Local Setup Modes, and route the video signals to provide the selected display. The selectable options are live video (V_A), playback video (V_B), V_A with the difference between V_A and V_B superimposed in color and a special video processor setup display in which V_A is differenced with itself and any residue is superimposed on V_A in color.

The analog differencing circuits subtract the live video (V_A) from the playback video (V_B). Nominal 1.0 volt p-p composite video/sync is fed to the processor via the V_A and V_B connectors on the rear of the chassis. V_B is fed directly to an input attenuator; V_A is fed to a filter network and then to an attenuator. The purpose of the filter network is to adjust the transfer characteristics of the line video channel to compensate for the disk recorder and TBC characteristics introduced in the playback channel. The final form of this filter network was determined during system integration.

The two input attenuators enable setting identical video peak white to video black (not sync) levels in both channels. Once these levels have been equalized, it is possible that different sync levels may exist in two channels. To correct this, each channel passes through a threshold network where the sync tips are self-clamped to an adjustable level

by diodes. These levels can be adjusted independently to cause the sync in each channel to be clipped by an equal amount below the video black level. This same network also established the DC input level for the following video differential amplifier. At the output of this network, the two video signals are identical (except for valid differences) between the master and UUT images, the sync tips have been clipped, and the signals are clamped to the same DC level.

The video is differenced in a dual output video amplifier. The two raw difference outputs corresponding to $V_A - V_B$ and $V_B - V_A$ are then fed to comparators, the differences are compared to adjustable thresholds and bilevel video outputs are generated whenever the raw video difference exceeds the threshold. Both bilevel outputs are high for differences greater than the threshold levels.

These two bilevel outputs are routed out of the video processor analog circuits to the digital circuits and are also routed within the video processor to the color enhancement network.

The color enhancement circuits present the difference video on the video monitor. The two bilevel outputs are routed through AND gates (which are enabled only when valid differences can exist) to the video driver network. This network consists of three amplifiers for driving the red, blue and green guns of the color video monitor. The live video input (V_A) is passed directly to the three drivers; this allows generating a black and white image of the UUT. The two bilevel difference outputs are summed into the live video signal ahead of the red and green drivers. Whenever these two levels are high (differences greater than thresholds), the black and white image will be superimposed with red or green color

showing the location of differences. Green will correspond to $V_A - V_B$ (UUT less dense than the master, back lighted mode); red will correspond to $V_B - V_A$ (UUT denser than the master, backlighted mode).

1.1.2.5 RBV Camera System

The RBV camera system, diagramed in Figure 1-5, consists of the following:

- The RBV electronics chassis.
- The RBV power supply chassis.
- Sync generator.
- Lamps and controls.
- RBV camera.

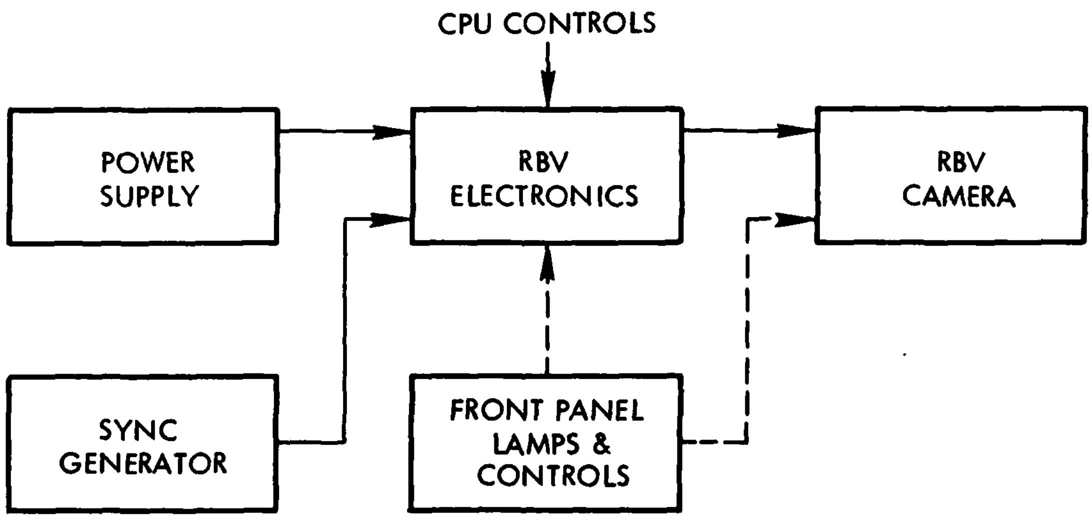


Figure 1-5 RBV Camera System

1.1.2.5.1 Camera Electronics

The camera electronics is located in the RBV electronics chassis. Its purose is to provide sweep signals and video signal conditioning for the RBV camera. This assembly contains twelve plug-in circuit boards (A1 through A12), two power supplies, front panel controls/ indicators, and a horizontal deflection driver.

- Horizontal Deflection Waveform Generator, A1

  This board contains a ramp generator used to provide linearity correction to the horizontal yoke driver. The ramp generator operates at the horizontal scan rate.

- Protection Circuits, A2

  These circuits detect the loss of horizontal and vertical deflection. Loss of either signal shuts down the high-voltage power supplies and lights the fault light on the RBV control panel.'

- Vertical Deflection, A3

  This board contains an oscillator, buffer, and yoke driver circuits. The buffer also sums the vertical steering voltage which provides vertical position control.

- Sync Buffers, A4

  Optical isolators are used to buffer and level shift the horizontal drive, vertical drive, and composite blanking signals from the sync generator.

- Target/Focus, A5

  This board generates a stable voltage reference and the focus coil and target drive signals.

- Beam/Alignment, A6

The horizontal and vertical alignment coil drive signals are generated on this board. The bias voltage for the RBV tube grid, G1, is also obtained from this card. There is also a circuit which produces a delayed clamp pulse which is supplied to A12.

- Electrode Regulator, A7

This board provides regulated bias voltages for the RBV tube grids, G2, G3, G4, G5, and G6.

- Beam and G4 Focus Control, A8

This assembly controls the beam and G4-focus voltages in accordance with the zoom ratio. A two bit binary word is used to specify the zoom ratio (1:1, 1.67:1, 3.60:1, and 10:1). The binary word is decoded to select a preset potentiometer for control of the beam and G4-focus voltages.

- Vertical and Horizontal Digital-to-Analog Converters, A9, A10

A9 and A10 are identical circuits used to control the vertical and horizontal position of the RBV beam. The beam position can be selected by the computer under CPU control or by the front panel switches under local control. The output of these boards (A9 and A10) provide the beam steering voltages to assemblies A1 and A3 respectively.

- Target, Horizontal Size, and Dynode Gain Control, A11

This assembly controls the target, horizontal size, and dynode gain signals based on the selected zoom ratio. Control of these signals is similar to that for the A8 board, i.e., a preset potentiometer is selected. In addition, drivers are provided for the front panel lamps which indicate the selected zoom ratio.

- <u>Video Driver/AGC, A12</u>

  A12 buffers and amplifies the video from the RBV camera. The buffered outputs drive the time-base-corrector, video processor, and the video monitor. In addition, this assembly combines the black burst and horizontal blank burst and horizontal blanking levels with the video signal. A AGC circuit is provided for the video preamplifier located in the RBV camera.

- <u>Horizontal Deflection Driver, A14</u>

  The horizontal deflection driver is a resonant flyback circuit operating at 15750 Hz. This board also provides linear correction and a summing point for the horizontal steering signals. Relays on the board provide the proper operation in accordance with each zoom ratio.

- <u>1500 V Supply, A18</u>

  A 900 V to 1200 V power supply is provided to drive the dynode as required by the corresponding zoom ratio.

1.1.2.5.2 RBV Power Supply

This assembly provides several DC voltages to the RBV electronics and camera assemblies. These voltages are ±6, -6.3, ±15, ±25, -400, +700, +2500. The assembly operates from 115 V, 60 Hz.

1.1.2.5.3 RBV Camera

The RBV camera consists of an RBV tube, the camera head electronics, and the focus and deflection coil assemblies. The camera receives sweep, and control grid voltages from the RBV electronics and returns a video signal which represents the image on the RBV tube face.

1.1.2.5.4 Sync Generator

The sync generator provides the sweep signals to the RBV electronics. These signals are vertical and horizontal drive, black burst, and composite blanking. This is a separate rack-mounted unit.

1.1.2.6 Illumination

The illumination system consists of an illumination controller, three illumination power-supplies, and three illuminator housings.

The illumination controller provides an intensity control signal to the illumination power-supplies. This provides for variation of the illumination intensity based on the selected zoom ratio. Zoom ratio information comes from the RBV electronics. Time delay relays are included to provide a lower than normal "cold-start" voltage when an illuminator is turned on.

The illumination power-supplies provide the voltages for the quartz-halogen lamps in the illuminator housings. There is one power-supply for each lamp. Remote sensing was added to each power-supply to compensate for voltage drops in the cables which connect the lamps with the power supplies. The remote sensing also helps to maintain a consistent voltage across the lamp for each preset illumination level.

The main power (115 V, 60 Hz) for the power-supplies is derived from the power distribution panel. There are two switches in the power distribution panel to manually operate the illuminators.

1.1.2.7 Video Devices

Four video devices complete the Control Display Station: the video disc recorder, time-base corrector, color video monitor, and sync generator.

The video disc recorder is used to store the image which is compared to the RBV video. The image stored on the video disc is V_B discussed in paragraph 1.1.2.4. This unit can store up to 400 images on each magnetic disk cassette. A remote control connector enables the unit to be controlled by the computer. A minimum of interface circuitry, located in the I/O processor chassis, completes the interface.

The time-base corrector (TBC) unit aligns the playback video, V_B, with the RBV camera video, V_A, to within 10 nsec. The reference signal is obtained from the sync generator unit described below. The TBC front panel provides a fine tuning of the alignment of V_B with respect to V_A. The TBC also supplies a 14.3 MHZ clock signal to the video processor digital circuits (paragraph 1.1.2.4).

A color monitor unit is used to provide the operator with a display of the V_A, V_B, or $(V_A - V_B) + V_A$ video signals. The monitor uses the system sync generated by the sync generator. A test signal is routed through an auxiliary video channel for alignment of the monitor. Video drive signals are routed from the AIME video processor (see paragraph 1.1.2.4) to each of the color-gun drive inputs.

A sync generator is provided as the AIME system time-base. The sync generator provides a variety of time and drive signals to various elements of the AIME system. Four signals are routed to the RBV camera system (paragraph 1.1.2.5): vertical drive, horizontal drive, composite blanking, and black burst. The video processor digital circuits (paragraph 1.1.2.4) utilize the first-field, vertical drive, horizontal drive, and composite blanking signals. A color bar test pattern signal is routed through the TBC and terminated in the color monitor. This signal is the system reference for TBC and a test signal for the color monitor.

1.1.3 Inspection Station

The initial proposed concept for the AIME Inspection Station envisioned a structure consisting of aluminum framing material to be used to support the RBV camera assembly. The aluminum frame material was readily available in standard sizes and considered to provide an economic rigid support for the RBV camera. The shroud was comprised of aluminum plates attached to the structure assembly with the shroud material contributing to the overall rigidity. The Inspection Station is diagrammed in Figure 1-6.

Further analysis during the design phase indicated, however, that the structure/shroud would have insufficient rigidity to maintain the 0.0005 inch orthogonality between the camera and holding fixture. A more rigid camera support was designed using bolted aluminum plates. The camera support, which is similar in appearance to microscope mount, was fastened directly to the optical table surface. In addition to proving more rigidity for the camera, the camera support provided a convenient mounting structure for both illuminators and mirrors.

Two frontal illuminators are located 180° apart and slightly defocused filament is imaged on the hybrid surface. The illumination angle established by an Illumination Analysis study for both illuminators was determined to be approximately 20°. In order to uniformly illuminate the 2" x 2" hybrid with the defocused filament image, the illuminators must be located 20 inches from holding fixture. To reduce the overall station width, both illuminators are mounted parallel to the RBV camera and adjustable mirrors are used to fold their beams (see Figure 1-7). The outside dimensions for the shroud are approximately 26" wide x 28" deep x 36" high.

A third illuminator, located on the optical table, has been provided to produce a back lighting mode. Light from this illuminator will be folded 90° by locating a mirror beneath the holding fixture (see Figure 1-8). Since scattered light from the illuminator or mirror incident on the front surface would decrease contrast, a bellows is used to completely enclose the light path between the illuminator and holding fixture.

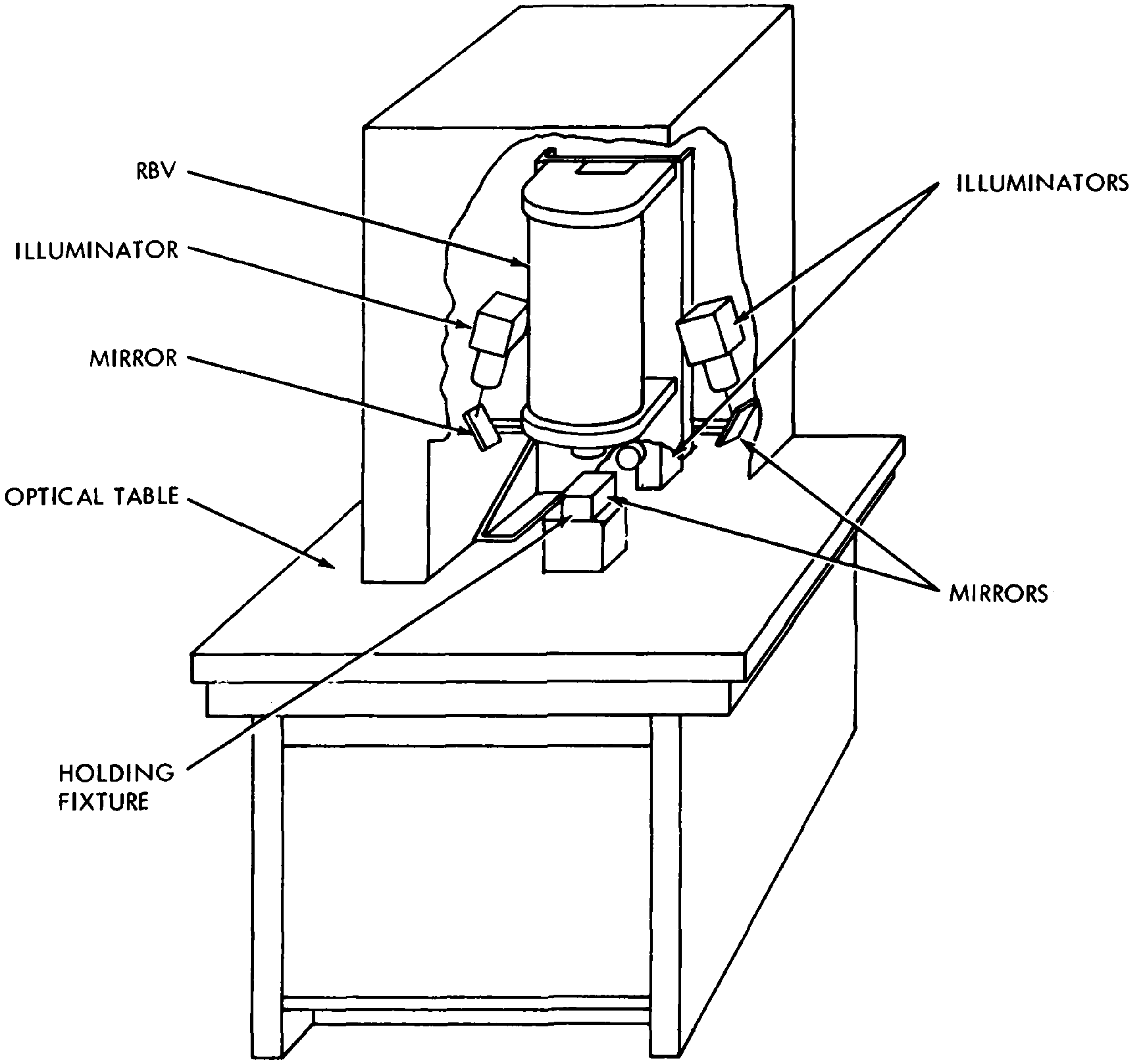


Figure 1-6. Inspection Station

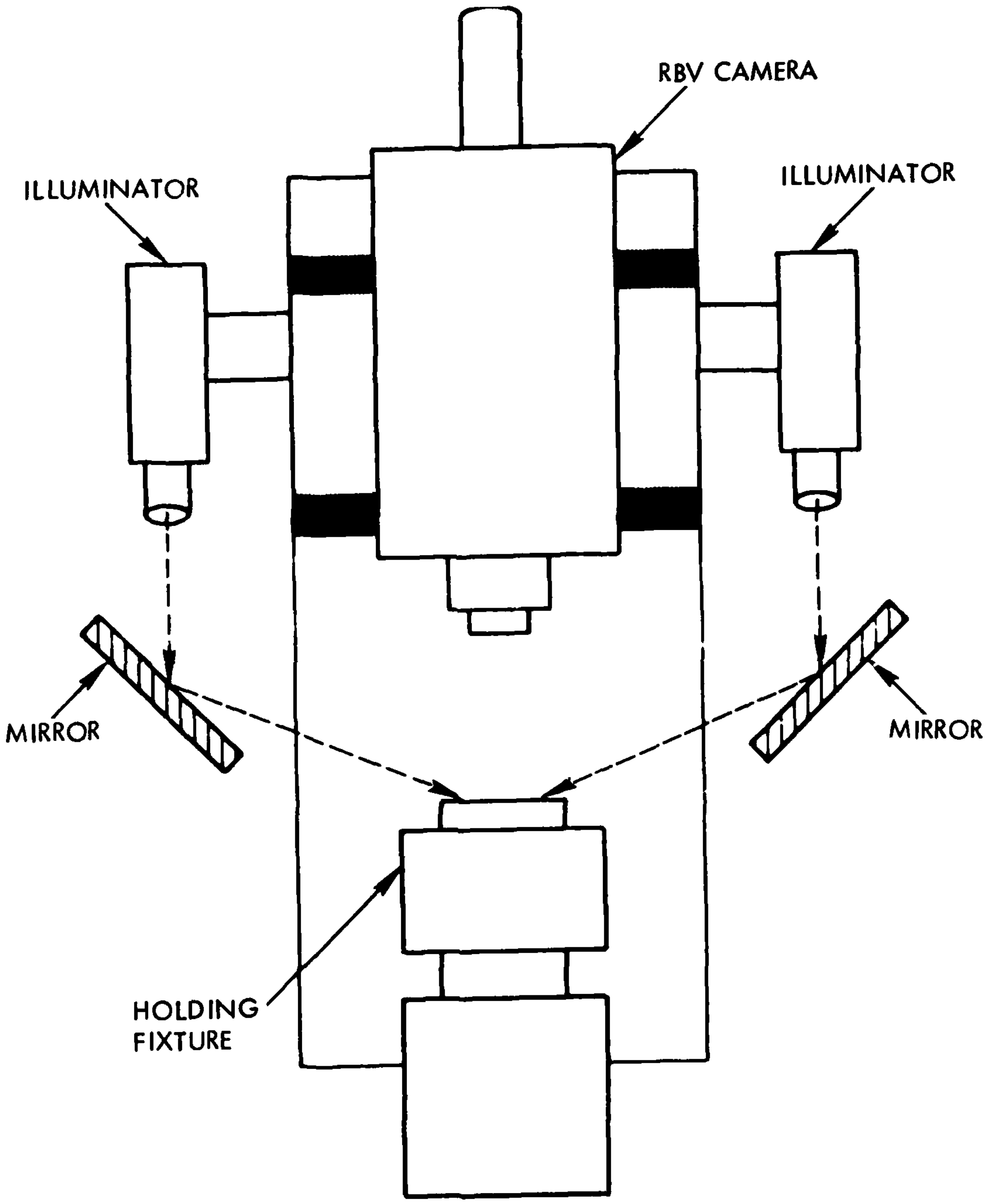


Figure 1-7. Front Illumination

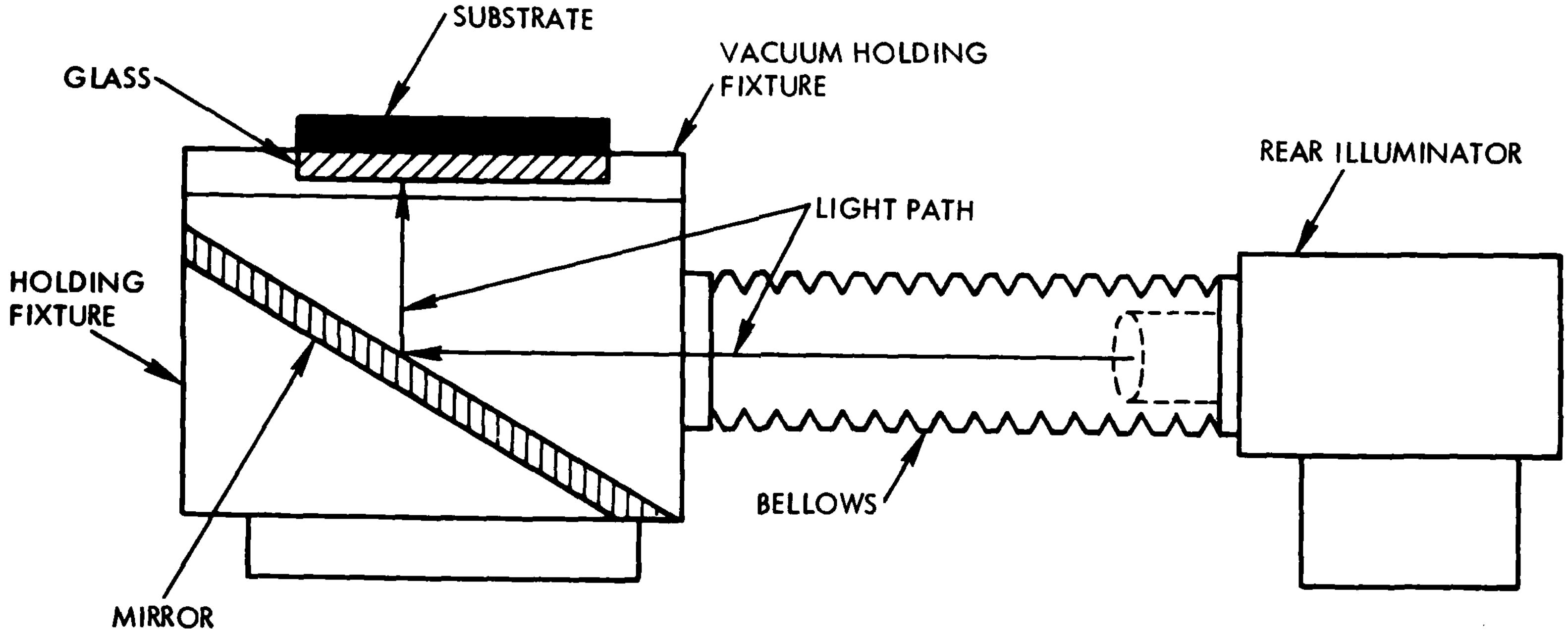


Figure 1-8. Rear Illumination

It was determined that vibrations generated by the illuminator cooling motors would cause RBV camera imaging difficulties. Therefore, the motors were disconnected and external cooling air from the air conditioner unit was ducted to each of the three illuminators. Air from the illuminators is exhausted directly into the shroud, thereby creating a slight positive pressure inside the shroud. This positive pressure precludes dust inside the shroud.

1.1.4 AIME Software

The AIME System Software will consist of Data General Real-Time-Disc-Operating System (RDOS), the Command-Line-Interpreter (CLI), the AIME-Run-Time System, and various utility programs.

1.1.4.1 Real-Time-Disc-Operating System (RDOS) and CLI

RDOS is a comprehensive and flexible operating system normally used with disc-based NOVA systems. RDOS provides a comprehensive file system that gives the user a simple command language to edit, compile, execute, debug, assemble, save, and delete files. File protection is provided by a number of system-defined file attributes. All peripheral devices are named and treated as files, providing device independence by device name. RDOS provides an I/O facility with buffered and spooled operations. The operating system allocates unused core storage for dynamic system buffers and overlays.

The Command Line Interpreter (CLI) is a dynamic interface to RDOS via the console and translates the input as commands to the operating system. The system restores the CLI to core whenever the system is idle - after initialization, after a disc bootstrap, after the execution of a program, etc. The CLI indicates that it is in control by inputting a ready message "R" followed by a carriage return.

1.1.4.2 Run-Time System

1.1.4.2.1 General

The AIME Run-Time System (ARTS) will perform the functions of program generation, and test execution. It will be written in high level language (ALGOL) utilizing structured programming techniques to obtain modularization for ease of maintenance and understanding. Assembly language modules shall be minimized and used only where necessary for speed or special purpose programming such as required in image processing. Certain existing software modules from the AIDE System have been used with minor modifications: AIMERTS INIT, GETLINE, LIGHT, READINPUT, READMEAS, RTSEXT, RTSTERM, and WAITFOR. The ARTS will operate under RDOS Rev 6.

The highest level software module will function an an interpreter which can be utilized in an on-line mode (manual mode), or execute a previously generated test sequence (auto or semi-auto modes).

Program generation will be accomplished either on-line or off-line. On-line program generation will allow the user to try various setups for X-Y position, zoom, illumination, etc. When a specific test setup is decided upon, the system software will remember, on operator command, the exact setup and will place the test setup in sequence with respect to other tests. Off-line programming will be accomplished by writing a legal sequence of interpreter commands and data. Upon execution of a program, any illegal commands or missing data will result in error messages being displayed to the user.

The result of either off-line or on-line program generation will be a source file listing, comprised of interpreter commands and data. This test program sequence is readily modifiable, through the use of a text edit program similar to the one used on the EQUATE AN/USM-410 system.

Actual testing is initiated by typing in the command 'TEST' on the CLI. If TEST/A 'NAME' is entered, the test sequence in the file 'NAME' will be executed in the automatic mode. If TEST/S 'NAME' is entered, the test sequence will be executed in the semi-automatic mode. Where 'TEST' is not followed by 'NAME', the system will be in the manual mode and will respond to and execute specific interpreter commands on the keyboard terminal.

1.1.4.2.2 Structure

Figure 1-9 shows the basic structure of the system control elements of the system software. The key elements are as follows:

- Input
  - via keyboard (manual mode)
  - existing test program (auto and semi-auto modes)
- Interpreter
  - interprets input command
  - checks for required data
  - calls appropriate software module
- Error Message Module
  - displays error message for improper command or data

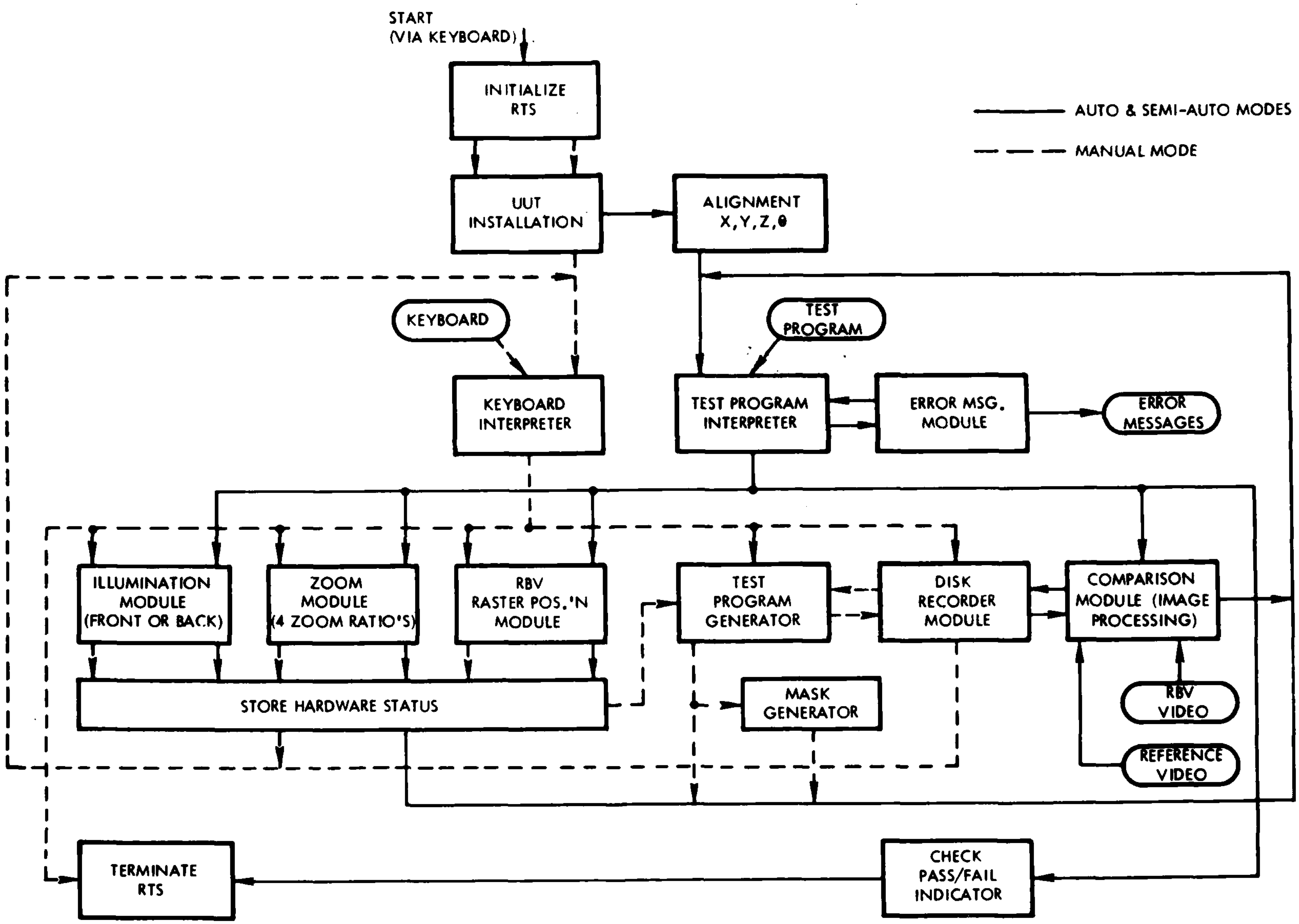


Figure 1-9. AIME Software Block Diagram

- Software Modules
  - one module for each major function
    - DISPLAY
    - RTS INITIALIZER
    - RTS TERMINATOR
    - XY POSITION
    - UUT ALIGNMENT
    - ILLUMINATION
    - ZOOM CONTROL
    - VIDEO RECORDER CONTROL
    - HARDWARE REGISTER CONTROL
    - IMAGE PROCESSING
    - PASS/FAIL DETERMINATION
    - TEST PROGRAM GENERATION
    - MASK GENERATION
  - returns to interpreter upon completion
- Common Data Storage
  - one 'external' module
  - accessible by all modules
  - stores current status of system hardware
- Keyboard Task
  - distinguishes between control keys and other inputs
  - allows direct control of hardware via keyboard
  - activates test program generation module with a 'TESTGEN' key

1.1.4.2.3 Test Program Generation

The test program generator will be used to create automatic and semi-automatic test programs for substrates and pre-cap hybrids respectively. To create a test program, the operator enters the command TEST. This will activate the system and enable the user to manipulate the system from the keyboard. Sectors have been designated for the user in positioning the image or the monitor. The higher the zoom ratio, the greater the number of sectors. Sectors are square in shape and are numbered from left to right and from the top down. When a suitable image is seen on the monitor the operator pushes the 'TESTGEN' keyboard button which results in the following system actions:

(1) Interrogation of all system status registers and storage of the current setup data for the image,

(2) The generation of a set of commands and related setup data, which when executed at a later date will result in the exact same setup conditions,

(3) Indexing and storage of the image on the video disc-recorder,

(4) The generation of a MASK for the current image for the automatic test program.

1.1.4.3 The Operator Keyboard

Figure 1-10 shows the configuration of the keys in the keyboard on the display terminal. The keys pertinent to the AIME system are summarized below:

- HALT — to terminate testing.
- PAUSE — to temporarily postpone execution of a program.
- PROCEED — when an operator action is required, this key is used to resume testing.

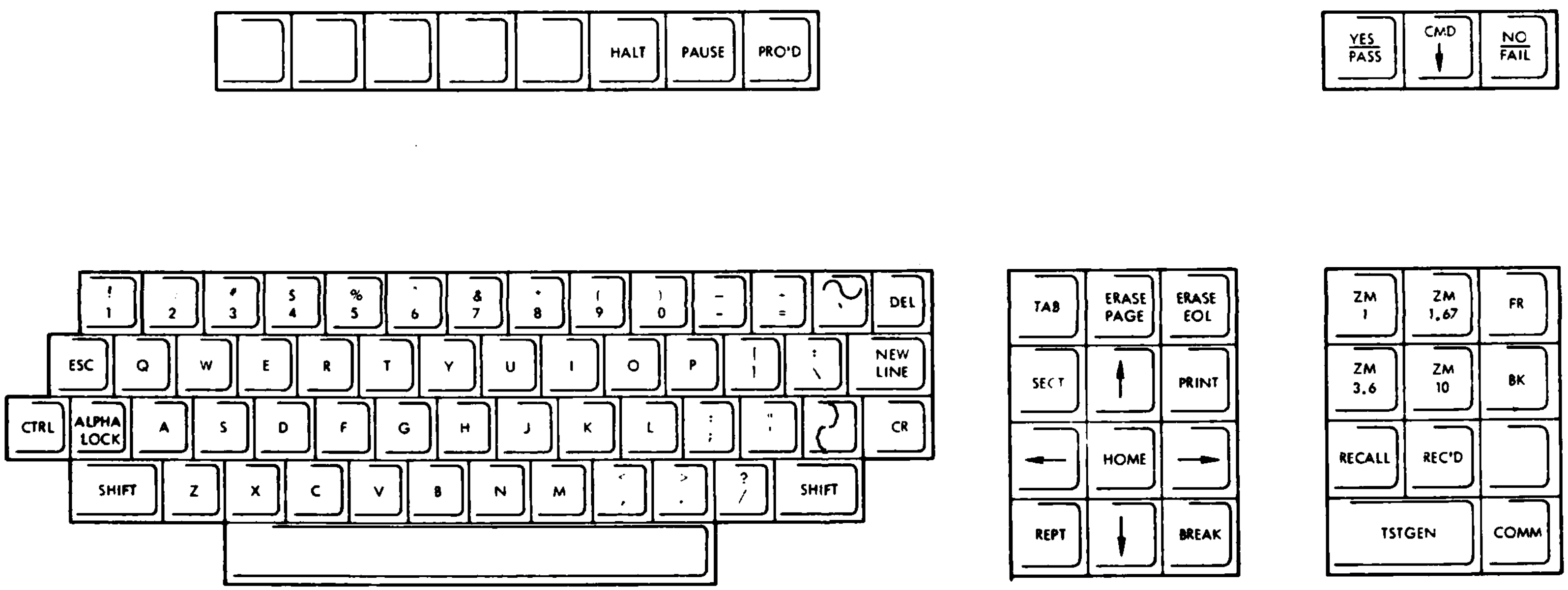


Figure 1-10 Operator Keyboard

- YES/PASS NO/FAIL — These dual purpose keys are used when responding to a YES/NO or PASS/FAIL decision.
- CMD — The 11 keys below the CMD buttom are recognized as test control commands only when the command is preceeded by the depression of the CMD key.

The 11 lower keys are primarily used while operating in the manual mode.

- ZM 1 ZM 1.67 ZM 3.6 ZM 10 — to select one of four zoom ratios for the RBV.
- FR BK — to select either front or back illumination for the UUT.
- RECALL — to recall a video image off the disc recorder for displaying purposes on the color monitor. The track is selected by the operator.
- REC'D — to record a video image onto the disc recorder, the track being selected by the operator.
- DIFF — to display the difference video on the color monitor.
- TESTGEN — to automatically generate a test program using the current setup conditions.
- COMM — this key is used in the semi-automatic mode as a means for the operator to store any applicable comments he may make.

The remaining keys are located on the middle keypad (Figure 1-8) and are used for image positioning:

- SECT — When a specific sector wants to be seen, depressing this key will ask the operator to input any sector number.
- HOME — This will position the RBV to sector 1.
- ↑, ↓, →, ← — These 4 keys will position the RBV to the appropriate adjacent sector.

Depending on whether the generated test program is to run in the automatic or semi-automatic mode, the proper command for computer image processing/computer decision or operator inspection/operator decision will be added. The user will then proceed by using the various commands to set up further images and repeating the process above, until a suitable number of reference images have been obtained. The test program generation process will then be ended when the HALT button is pressed. This will add a pass/fail decision command to the end of the test program. The resultant test program can be printed out at any time for reference or permanent record.

1.1.4.5 Mask Generation

The mask generator (software module MASKGEN) will be used to generate a mask for each reference image operating in the automatic mode. Where an etch boundary exists, the mask will consist of a block of 'Ø's with '1's elsewhere. The width of the block of 'Ø's will be sufficient magnitude to mask out offset and registration errors. The resultant mask will then be stored as a disc file. During an automatic mode run, the appropriate mask will be read into the computer memory and "AND ed" with the difference video data. The resultant data is then ready for the image processing.

1.2 PHYSICAL DESCRIPTION

Figure 1-11 shows the physical layout of the AIME system. There are basically two major units of the AIME demonstration system:

- Control/Display Station
- Inspection Station

Figures 1-12 and 1-13 illustrate the actual Control/Display Station and Inspection Station respectively.

1.2.1 Control/Display Station

The Control/Display Station consists of two racks which contain all the control and processing electronics in addition to the video monitor unit, a separate table for the display/keyboard unit, and a stand alone character printer.

Both racks are 78" high, 30" deep, and accommodate standard 19" wide panels. The right hand unit has a pull-out writing surface located just below the video monitor. Also, in this rack are the power supply units for the RBV electronics and illuminators. The AIME power distribution and RBV electronics chassis complete the right rack assembly.

The left rack consists of the computer and disc, video recorder, sync generator, and timebase corrector, as well as the I/O Processor chassis. Both racks contain their own blower assemblies for cooling. The racks are connected together to form a single unit. There is no center panel separating the two racks. Elimination of this panel permits easier inter-rack wiring.

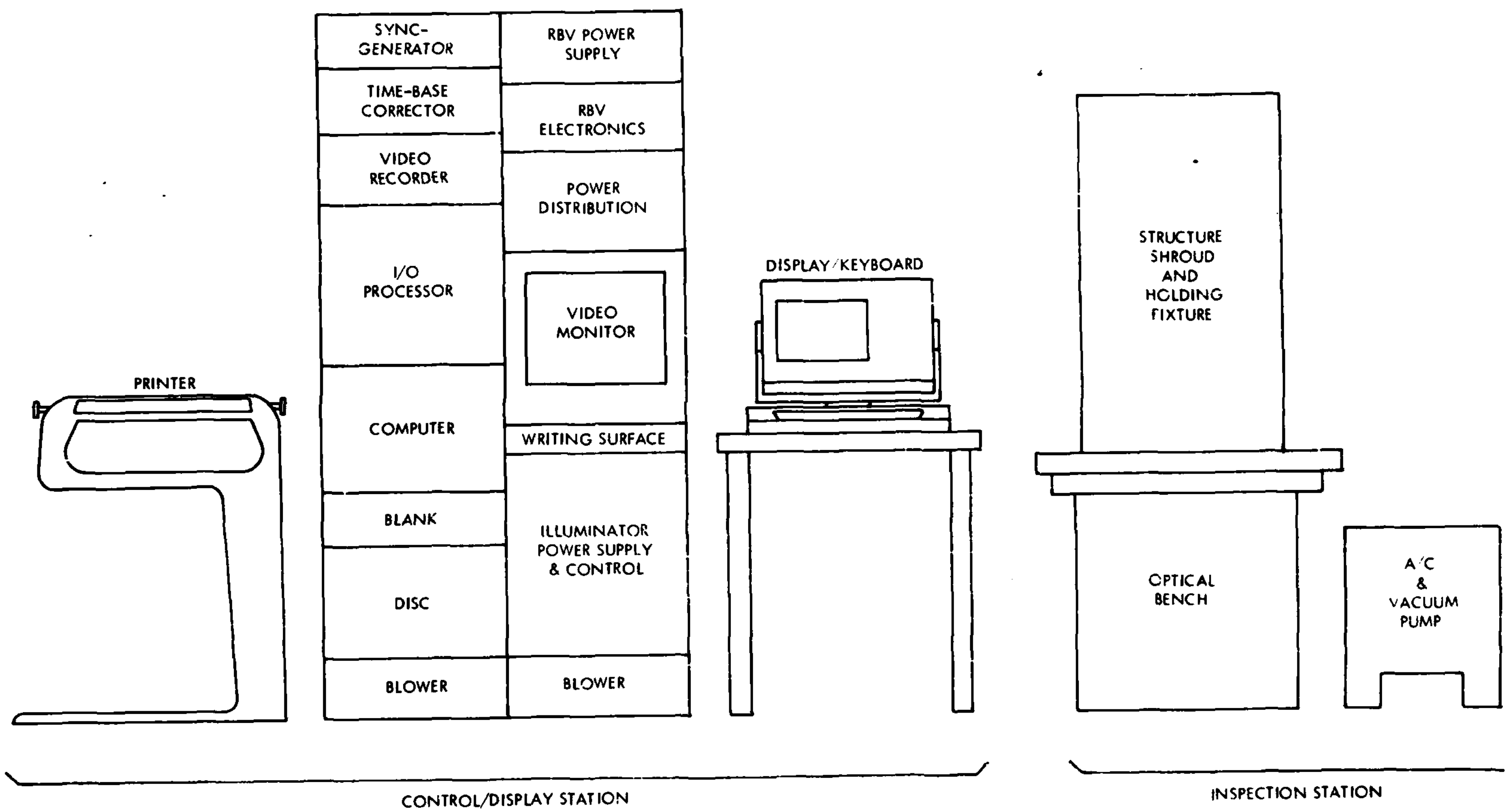


Figure 1-11 .AIME Demonstration Configuration

Figure 1-12. Control/Display Station

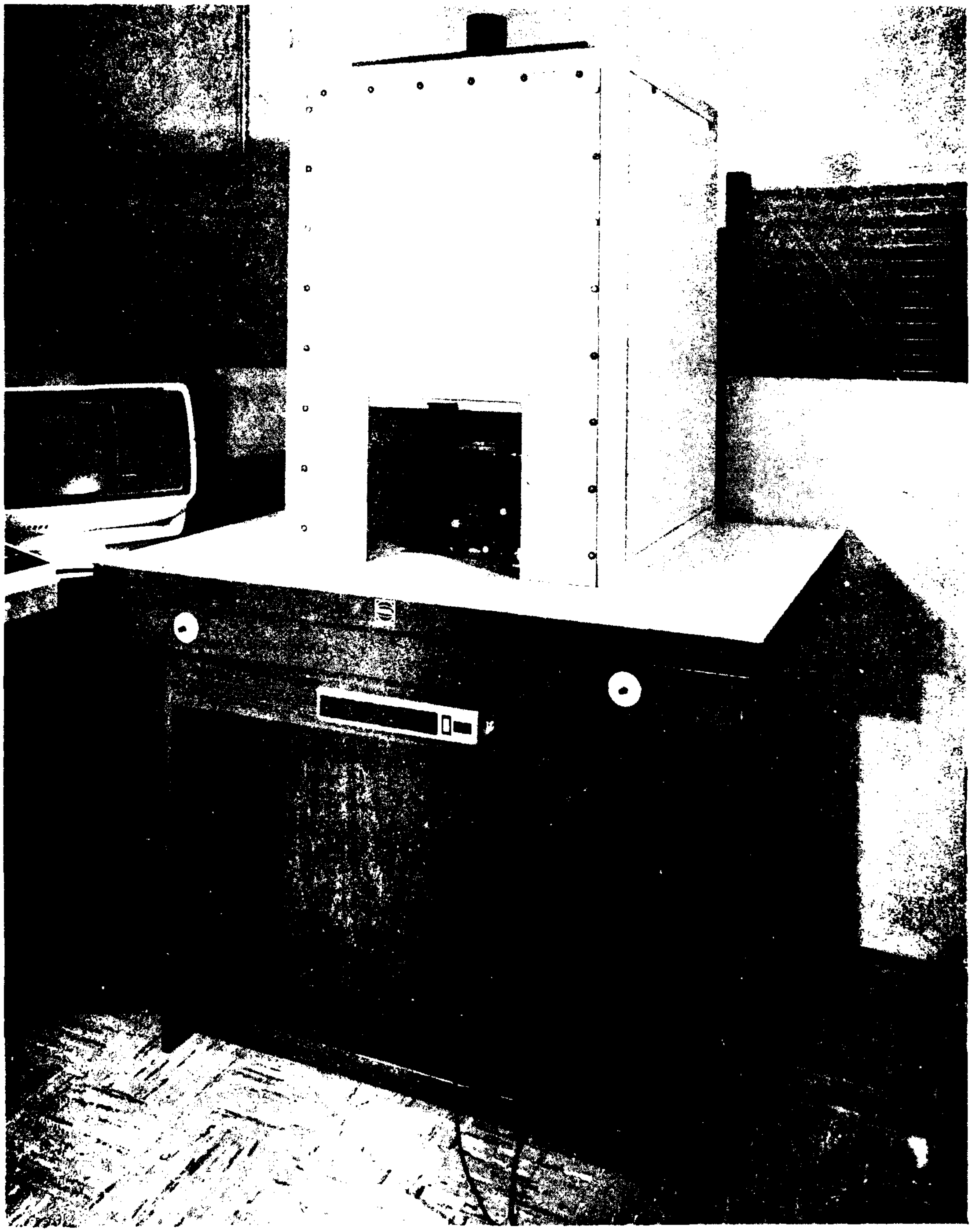


Figure 1-14. Inspection Station

Table 1-2 contains the major physical characteristics of the elements contained in the Control/Display Station.

TABLE 1-2 Control/Display Station Elements Physical Characteristics

DEVICE	WEIGHT (lbs.)	DIMENSIONS H x W x D), inches
Computer	130	10.5 x 19 x 21
Disc Subsystem	157	10.5 x 19 x 30
Display/Keyboard	52	15 x 22 x 21
Printer	60	33.5 x 27.5 x 21
Video Disc Recorder	38	6.5 x 16.24 x 17.5
Time-Base Corrector	60	8.75 x 17 x 20.5
Color Video Monitor	98	18.5 x 17 x 22
Illumination Power Supply (3 total)	100	11 x 11 x 6
Sync Generator	21.5	19.2 x 19 x 3.5
I/O Processor Chassis	61	16 x 17 x 19
RBV Electronics Chassis	25	11 x 17 x 19
RBV Power Supply Chassis	47	5 x 17 x 19
Power Distribution Chassis	25	7 x 17 x 19
Blowers (2 total)	25	7 x 17 x 19

1.2.2 Inspection Station

The Inspection Station diagrammed in Figure 1-14 contains the vertically mounted RBV, three illuminators, and hybrid holding fixture. Because of the rigidity required, the

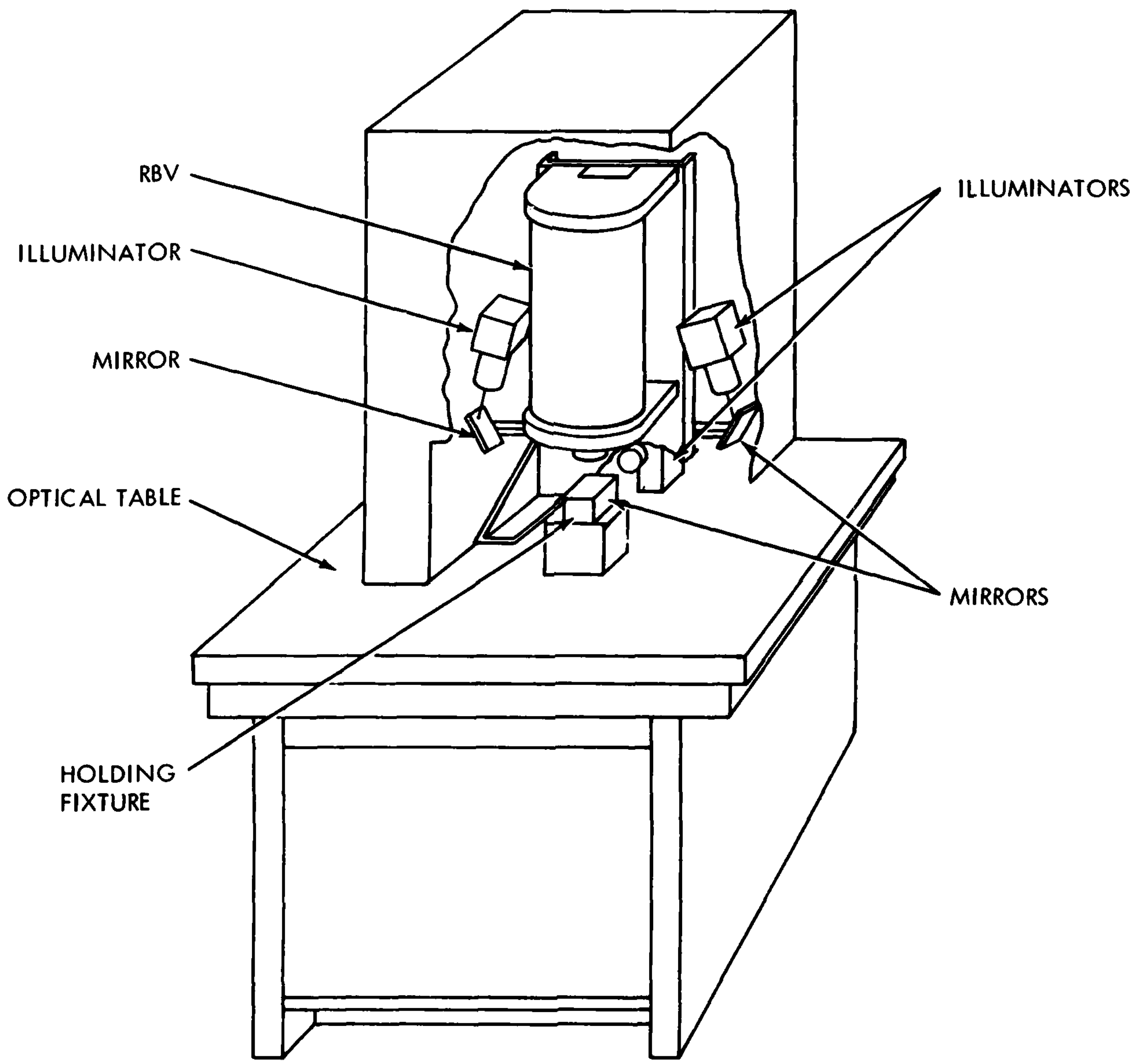


Figure 1-14. Inspection Station

Cooling air for the RBV and illuminators is provided by the air conditioner unit which consists of a standard 5000 BTU window type air conditioner; a 300 CFM centrifugal fan; air collection plenum; dual outlet tubes with dampers; connecting hoses. To reduce vibrations, the air conditioning unit is located remote from the inspection station and its output is ducted through flexible hoses. The small vacuum pump is mounted on top of the air conditioning unit and provides a 25 liter per minute vacuum for the holding fixture.

The holding fixture provides four degrees of freedom, a vacuum holding capability, and precise three point locating pins as shown in Figure 1-15. Three translation stages are used to produce x, y, and z positioning. Angular positioning is obtained by fastening the orthogonally mounted translation stages on a plate, which is attached to the angular, θ, adjustment stage. A thumb screw is provided to secure this adjustment. Three guide pins provide a repeatable reference on the stainless steel reference plate. The reference plate is located on the mirror holder assembly. This assembly houses the mirror which is used for back-illumination. There is also a cut-out section in the reference plate. This cut-out is large enough to implement the back-illumination as well as accepting a special holding unit for smaller than 2" x 2" hybrid or substrate assemblies.

The optical table is fabricated from a very strong, light weight, all metal honeycomb structure with a precision ground stainless steel top surface. An array of 1/4-20 tapped holes on two inch centers allows the stable mounting of bolted accessories.

Three illuminators are mounted inside the shroud and on the structure. Two of the illuminators are mounted to the left and right of the RBV assembly. The third illuminator is mounted behind the RBV.

The light from the illuminators will be projected on the UUT via three mirrors. By this method, there will be two illuminators for illuminating the top of the UUT and the remaining illuminator will be used for back-illumination.

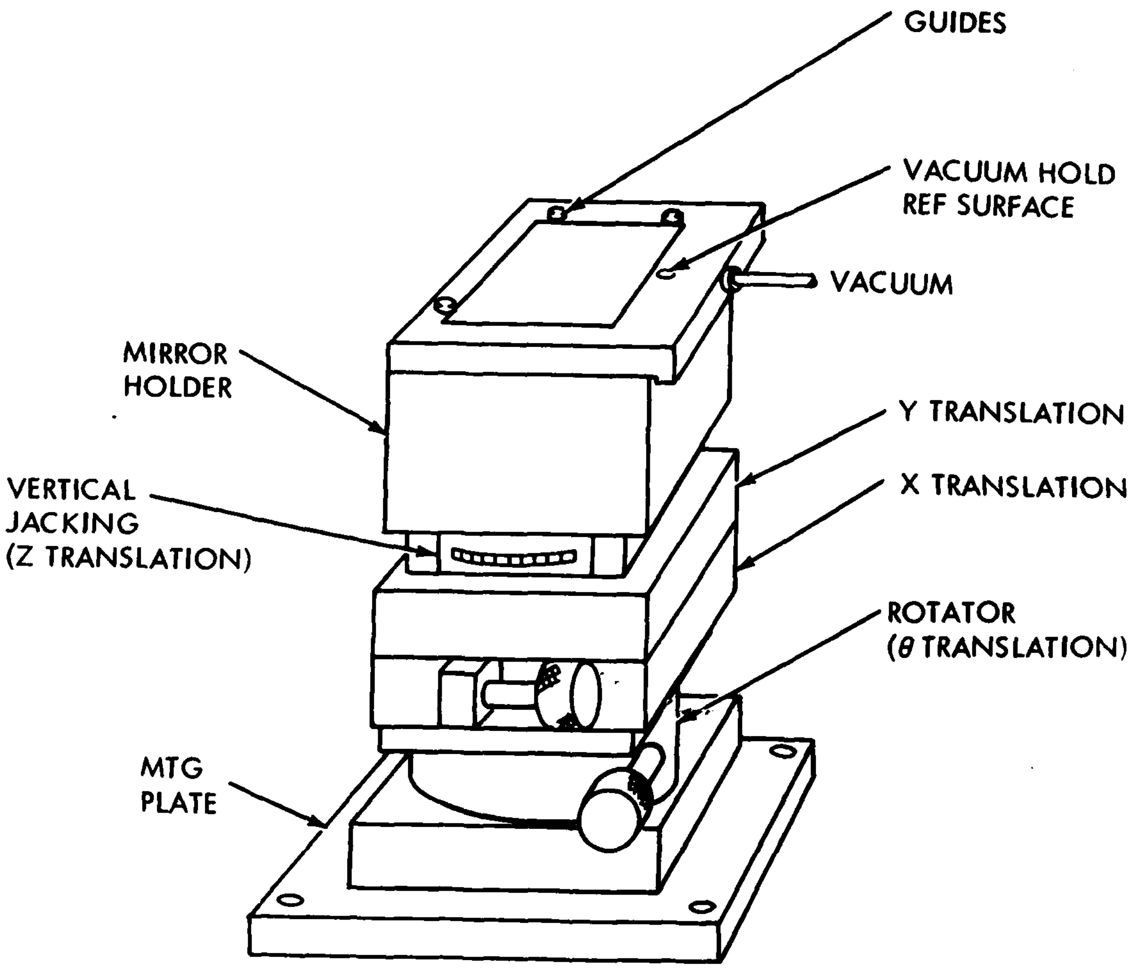


Figure 1-15. Holding Fixture

1.3 SYSTEM OPERATION

During the visual inspection process, the AIME system executes certain operations. These operations setup the proper conditions required to obtain the data necessary for evaluation of the Unit Under Test (UUT) either a substrate or pre-cap hybrid assembly. Summarized, these operations are:

- The selection of either front or back illumination of the UUT.
- The selection of zoom ratio or magnification factor of the UUT image.
- Sector or position selection of the UUT image which determines the area to be evaluated.
- Video disk recorder operation to record or retrieve the reference video image. This is the image to which the UUT will be compared when evaluating thick-film substrates.
- Display control of the video monitor.
- Test program generation. This is the AIME system's capability to automatically create a test sequence program which is used to inspect a UUT.

The test system evaluates the UUT in either of the two ways:

(1) By presenting a magnified image of the UUT on a video monitor for evaluation by the test system operator.

(2) By an automatic process which evaluates digital data inputted to the computer. The digital data represents a computer core image of the faults contained on the UUT.

All these operations are necessary in some repeatable sequence for the successful inspection of a printed substrate or pre-cap hybrid assembly.

1.3.1 Operation Modes

Execution of these operations is under the complete control of the computer/control subsystem. Interventions by the system operator are minimized to optimize the inspection process. These operations can be executed in three (3) distinct ways.

1. In the Manual Mode the operator has the capability of selecting any combination of operations to suit his needs. This mode can be used to inspect printed substrates or pre-cap hybrid assemblies.

2. In the Semi-Automatic Mode is is assumed that a test sequence has been generated for a particular UUT. Operation in this mode means the execution of this predetermined sequence with the sequence stopping after the test conditions have been setup. This mode of operation can be used to inspect printed substrates or pre-cap hybrid assemblies.

3. In the Automatic Mode, the entire test and evaluation sequence is under complete control. This process is intended only for the inspection of printed substrates. The only required operator action is installation of the UUT in the Inspection Station and the start of the inspection process. Like the semi-automatic mode, an inspection sequence must have been previously generated.

Control of these operations by the computer/control subsystem ensures that each execution of a required operation will be identical each time it is performed. Although the video processing and evaluation is relatively complex, the computer execution time is extremely fast. This results in location and evaluation of substrate defects significantly faster than can be performed by microscope further, the use of a programmed test sequence ensures that no selected area of the UUT will miss visual inspection.

1.3.2 Illumination: Control

Control of the illumination provides the selection of either front or rear illumination. Selecting front illumination allows the operator to illuminate the top of the UUT. Rear illumination allows the operator to illuminate the UUT from the back. The rear mode is intended only for translucent printed substrates and can be used with substrates that have a high precentage of rear surface metalization. The level intensity of the illumination is determined by the requirements of RBV camera located in the Inspection Station. These levels are preset and are keyed to the zoom ratio selected.

1.3.3 Zoom Ratio

The AIME Demonstration System allows the selection of four possible zoom ratios of magnification factors. This allows a close-up inspection of the UUT. The inspection area for a given zoom ratio is provided in the table below:

Zoom Ratio	Dimensions of the Inspected Area
1:1	2" x 2"
1,4:1	1.44" x 1.44"
3,6:1	.60" x .60"
10:1	.22" x .22"

Note that for zoom ratios greater than 1:1, a small amount of overlapping (10%) is is given to minimize any errors due to boundary conditions at the edges of RBV image and ensure that the entire surface of the test specimen is evaluated.

1.3.4 Position Selection

When zoom ratios of either 3,6:1 or 10:1 are used, the RBV image must be repositioned so that the entire UUT can be inspected. This is done by specifying the X and Y coordinates of the center of the desired RBV image. This has been simplified for the operator by supplying him with a map of the UUT inspection area on the computer display. This map is divided into sector numbers, the total number of which is determined by the zoom ratio selected. There are 4 sector positions for the 3,6:1 zoom ratio and 49 sector positions for the 10:1 zoom ratio. A 1.4" by 1.4" inspection area (that of the test substrates) is assumed.

1.3.5 Video Disc Recorder Operation

The video disk recorder is used to store the referenced images of the selected UUT sector. The computer/control subsystem maintains the status of this device by reading, via remote lines, the present mode of operation. The computer will modify the mode as required to accomplish the required task. The functions which can be performed are:

- track selection
- recording of a video image
- playback of a video image

1.3.6 Video Monitor Display Control

The image presented on the Video Monitor can be controlled by the computer. There are three (3) possibilities:

1. Display of the live RBV image which represents the selected view of the UUT.
2. Display of the video disk reorder output which represents the stored reference images.
3. Display of the live RBV image with the video differences data superimposed. The video difference data is the algebraic difference between the live RBV (V_A) and the video disc recorder (V_B). If there is an area over which $V_A > V_B$ a red color is superimposed. If an area exists where $V_B > V_A$ then a green color is superimposed on the video monitor display.

1.3.7 Test Program Generation

A test sequence can be generated in the Manual operating mode by setting up the illumination, zoom ratio, and sector and depressing a "TESTGEN" button on the computer terminal keyboard. The computer will store these settings and append them to the source file indicated by the operator. The source file then represents the inspection sequence for the UUT.

Once a test program has been generated, it can be executed in two (2) ways, the automatic mode or the semi-automatic mode.

SECTION 2

PROGRAM ACCOMPLISHMENTS

2.1 SYSTEM ANALYSIS

During the initial phase of the program system studies/analyses were conducted to convert the thick-film hybrid visual inspection requirements (Method 2017.1, MIL-STD-883A) into definitive AIME system concepts and baseline design requirements for the demonstration model hardware and software. These analyses include:

1) Review of typical conductor faults in hybrid thick-film substrates and visual inspection acceptance/rejection criteria to establish the design characteristics of The AIME demonstration model. This analysis also served as the design criteria for the test sample substrates that were fabricated to evaluate demonstration model performance.

2) An illumination analysis to establish illumination design characteristics (type, intensity, spectral properties, geometry) for the demonstration model.

3) An investigation into other possible visual inspection techniques using other than an RBV scanning system.

4) An investigation into the system operation timing requirements to confirm that the design concepts postulated for the demonstration model were applicable to a "production system" with an operation goal of 750 substrates/hour.

5) Development of an AIME misregistration error budget.

The above analyses were conducted and incorporated into the system concepts and baseline design requirements, which were reviewed and approved by the ERADCOM Technical Monitor at the AIME Preliminary Design Review, conducted at RCA-Automated Systems, 31 January 1978. Details of these analyses are provided in the following paragraphs.

2.1.1 Hybrid Analysis

This analysis considered a review of typical conductor faults in hybrid thick-film substrates that result from normal printing, probing and work-in-process handling in general. The analysis specifically addressed the requirements of the contract to demonstrate automatic inspection of good and deliberately faulted substrates.

2.1.1.1 Demonstrate Substrates

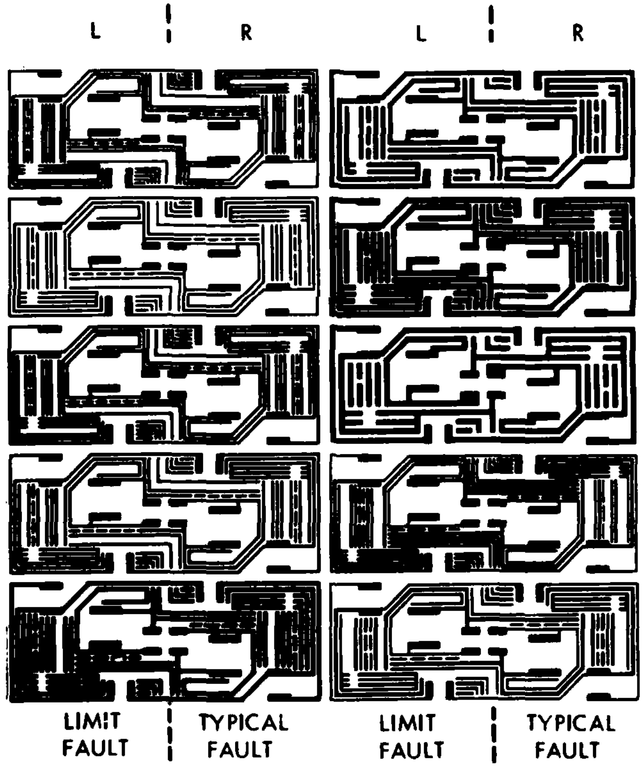
Table 2-1 delineates the substrate defect types that were selected for use in the AIME evaluation. Each of the 10-image substrates that were produced for this purpose take the form shown in Figure 2-1. Each of the 10 images on the substrate contain lines with the different widths and different spacing designted around the border in the figure. The basic types of patterns are similar to one another, differing only as the conductor densities differ. There is a right-hand and left-hand symmetry to each of the 10 patterns. This approach allows a fault to be placed in each half of the same substrate at topographically similar locations. One fault is designated to simulate a "spec-limit" condition and the other fault, to simulate a more *typical condition.*

There are two groups of demonstration substrates necessary to show AIME equipment performance at two critical in-process substrate inspection points: (1) after printing and drying of the gold conductor layer and firing the resistor layer that uses 100K ohm/square ink. The demonstration points in the processing are depicted in Figure 2-2 by the inspection triangles with double lines. Note that no automatic inspection was planned when the inks are wet even though such an inspection would be very desirable for production versions of AIME type equipment. After all, this is the inspection point that can be most effective in identifying an out-of-control process and for initiating immediate corrective action. But "wet" ink inspection demonstrations are impractical on this program simply because of the logistics of handling in conjunction with on-going hardware/software debugging.

Table 2-1. Demonstration Substrates

LOT NO.	DESCRIPTION OF 10-IMAGE SUBSTRATE PLATES	NUMBER OF SUBSTRATE PLATES	
		DRIED GOLD	FIRED GOLD/RESISTORS
1	FAULT FREE	10	10
2	OPEN CONDUCTORS (VOIDS)	2	2
3	SHORTS & WHISKERS BETWEEN CONDUCTORS	2	2
4	NO PRINT OF SELECTED CONDUCTORS	2	2
5	NARROW CONDUCTOR	2	2
6	WIDE CONDUCTOR	2	2
7	SCRATCHES	2	2
8	MISLOCATED LINES	10	10
9	SMEARED LINES	2	2
10	COMBINATION OF 2, 3, 4, 7 & 9	2	2

PATTERN NO.	LINE WIDTH (Mils)	LINE SPACING (Mils)
1*	4	4
2*	4	6
3*	5	4
4*	5	5
5	8	5



PATTERN NO.	LINE WIDTH (Mils)	LINE SPACING (Mils)
6	8	8
7	10	5
8	10	10
9*	4 & 6	4
10*	4 & 6	6

* FINE LINE PATTERNS

Figure 2-1. Multiple-Image Demonstration Pattern

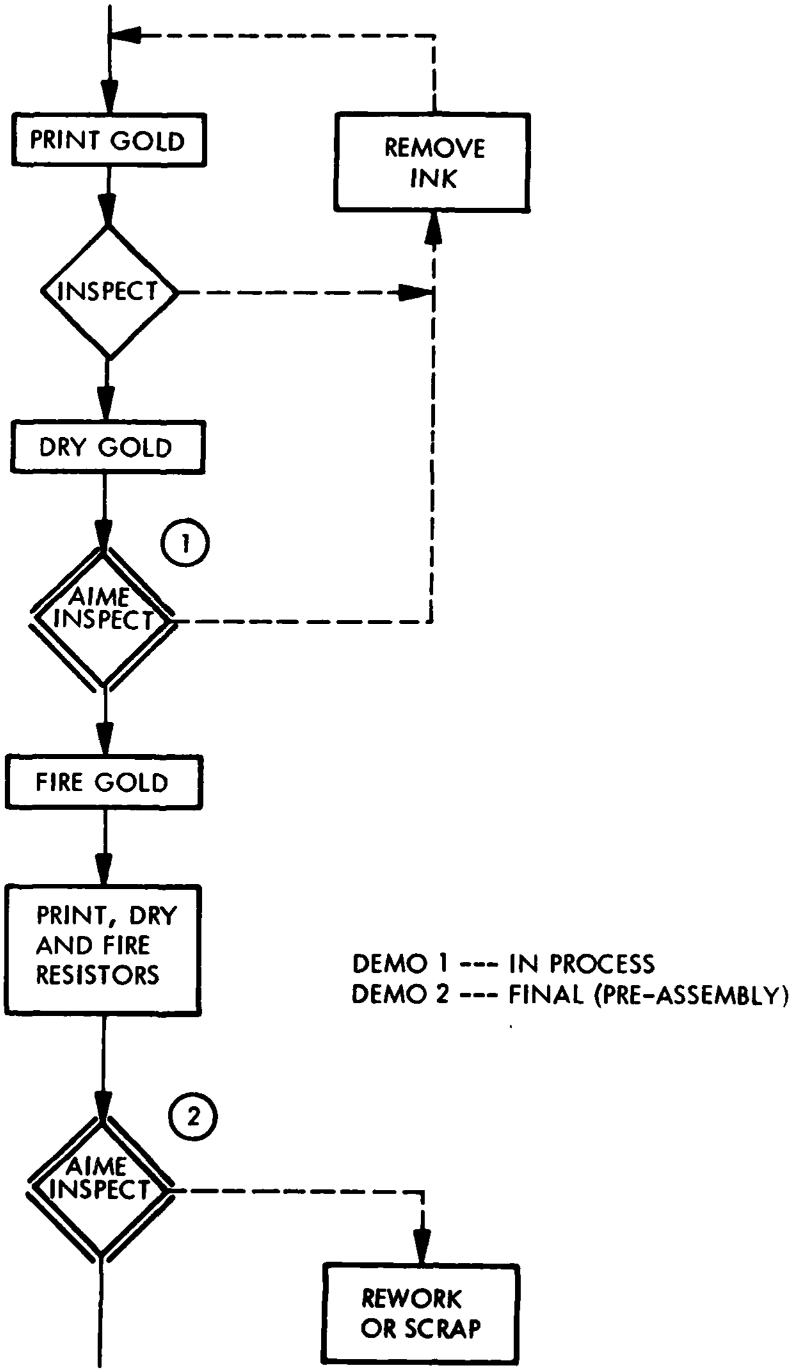


Figure 2-2. Demonstrations of Substrate Inspection

The two inspection points that were demonstrated are meaningful points in a real production flow. Corrective action can be taken on printed substrates rejected after drying before firing: and the final substrate inspection is routinely performed normally on a 100% basis before moving the substrates on to the next level of assembly where chip parts are added.

2.1.1.2 Substrate Faults

2.1.1.2.1 Substrate Cracks

Table 2-1 identifies all faults and fault combinations delineated in the Statement of Work except for substrate cracks. In general, substrate crack widths fall below the 0.5 mil resolution of the demonstration system. To develop the hardware necessary to automatically detect cracks would expend time and money beyond the scope of this effort. In addition, substrates rarely stay cracked during substrate printing, drying and firing. They break! The potential for cracking during assembly is less rare, therefore although no automatic inspection was attempted on cracked substrates, manual inspection in the pre-cap hybrid mode was assessed using specimens of RCA Automated Systems (RCA-AS) products known to have substrate cracks.

2.1.1.2.2 Basic Methods for Simulating Substrate Faults

2.1.1.2.2.1 Designed Faults in Screens (Masks)

The following faults identified in Table 2-1 were simulated by appropriate modification of the basic layout of the 10-image pattern:

Lot No.	2	Opens (voids)
	3	Shorts and Wiskers
	4	No Print
	5	Narrow Conductor
	6	Wide Conductor
	10	Combination (as applicable for above faults)

2.1.1.2.2.2 Manually Induced Faults

The following faults identified in Table 2-1 were simulated by manual faulting of printed substrates:

Lot No.	7	Scratches
	9	Smeared Lines
	10	Combination (as applicable for manually induced faults)

Lot No. 8 for mislocated lines is a special case in which the faults were produced by deliberately misaligning the substrate by known amounts during the printing operations.

2.1.1.2.2.3 Distribution of Faults

The 10 different images defined by Figure 2-1 can be divided into two basic groups: a fine-line group and a medium-line group. For some of the fault types it was useful to take advantage of similarities between the two groups to derive more information from the test samples. For example, all patterns with 4-mil lines can have identical void patterns introduced on the conductors, but the designed fault can be located differently on each of the patterns. Thus the local region around the fault will present a different video picture to the system even though the faults are the same. Similarly, all patterns with 4-mil spaces between conductors can have identical short circuits introduced at different locations on the patterns.

2.1.1.2.3 Detailed Fault Description

The following paragraphs describe the faults that were provided in the demonstration substrates.

2.1.1.2.3.1 Open Conductors (Voids)

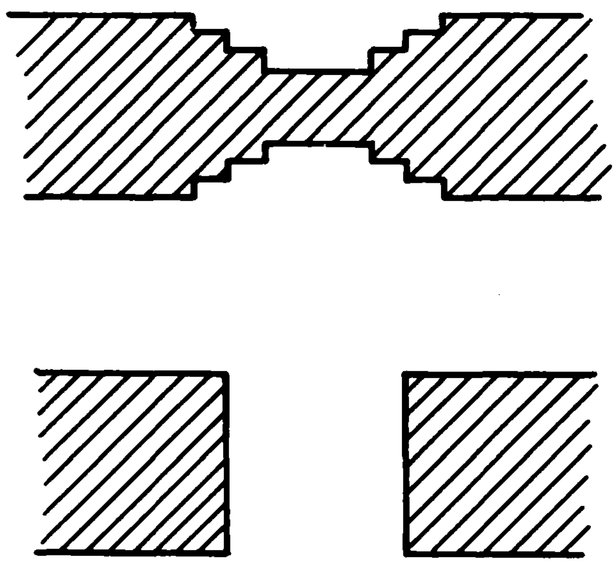
Open conductors (or voids) typically occur during the printing process because of a plugged screen caused by lint or drying ink. Voids were designed into the layout itself so that faults of lot no. 2 could be produced in a controlled manner. Figure 2-3 illustrates the design of conductor voids. Note that in addition to a limit type fault, three sizes of typical faults were provided, one of which is illustrated. The other two faults close the gap between conductors to 1/2 and 1/3 the separation shown. The designed faults were distributed as follows among the 10 patterns in accordance with the general thinking outlined in paragraph 2.1.1.2.2.3.

Fine Line Patterns:

Pattern No.	
1	Faults on long horizontal line: Limit and typical size 1
2	Faults on long vertical lines: Limit and typical size 1
3	Faults on short horizontal line: Limit and typical size 2
4	Faults on short vertical lines: Limit and typical size 2
9	Faults on vertical lines: Typical size 2 and typical size 3
10	Faults on horizontal lines: Typical size 2 and typical size 3

Medium Line Patterns

Pattern No.	
5	Faults on long horizontal line: Limit and typical size 1
6	Faults on long vertical line: Limit and typical size 1
7	Faults on short horizontal line: Limit and typical size 3
8	Faults on long vertical line: Limit and typical size 3



LIMIT FAULT

(LESS THAN 50% OF ORIGINAL WIDTH LEFT UNDISTURBED)

TYPICAL FAULTS

SIZE 1: 1-SQUARE OPEN (AS SHOWN)
SIZE 2: 1/2-SQUARE OPEN
SIZE 3: 1/3-SQUARE OPEN

Figure 2-3. Fault Designs: Open Conductors (Voids)

2.1.1.2.3.2 No-Print of Selected Conductors

"No-print" conditions make open conductors as deadly to a hybrid circuit as the voids discussed in 2.1.1.2.3.1. But the causes of no-print conditions are different. If the printer has not been set up properly or gets out of adjustment, defective printing occurs. But even with proper adjustment of equipment, a line or lines can misprint because of a poor substrate - one with excessive camber. A "no-print", in fact, quite often leaves behind some line indication with mesh marks.

Figure 2-4 shows the design for faults due to missing printed conductor in varying degrees. At the top of the figure is drawn a "Limit fault" that in effect simulates a condition where continuity still remains in the conductor at the two edges of the design line. But then less and less material is left behind in the typical faults simulated below the limit fault.

Following an approach similar to that described for voids in 2.1.1.2.3.1, the different degrees of fault conditions were appropriately distributed at different relative locations among the 10 patterns.

2.1.1.2.3.3 Shorts and Whiskers Between Conductors

Shorts and whiskers are formed during the printing process primarily due to printer adjustment problems with poor screen breakaway from the substate. A low viscosity ink can cause the problem as well as excessive camber. The fault conditions are more likely in large-area screen printing that challenges the printer to its limit.

Figure 2-5 shows the fault designs to simulate printed defects by means of the layout. Note that these faults are essentially the opposite of voids. The faults were distributed among the Fine Line Patterns and Medium Line Patterns in accordance with the same plan as shown for voids (para. 2.1.1.2.3.1); e.g., pattern No. 1 contains faults on a long horizontal line with the left-hand side of the pattern containing the limit fault and the right-hand side of the pattern containing the typical size-1 fault.

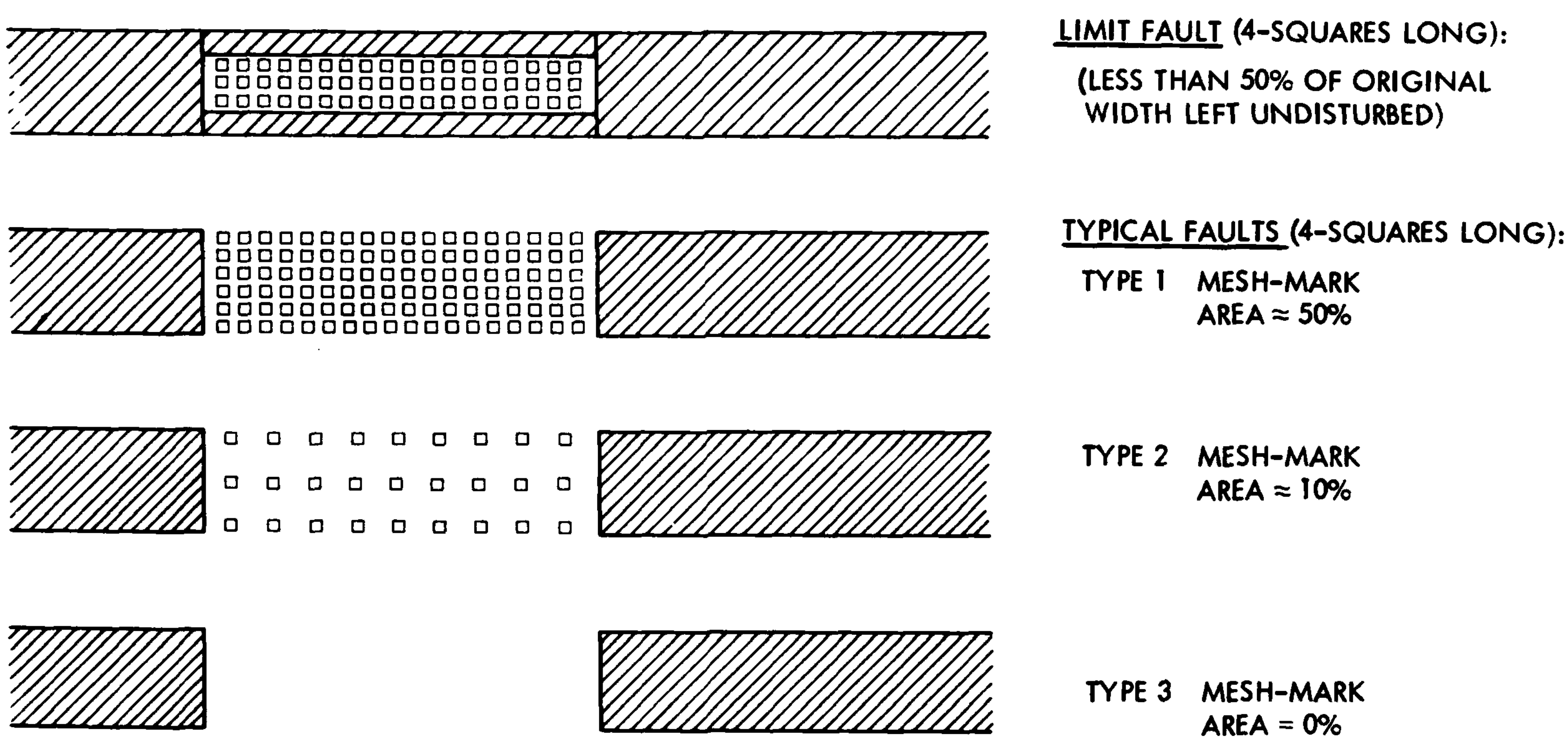


Figure 2-4. Fault Designs No Print of Conductor

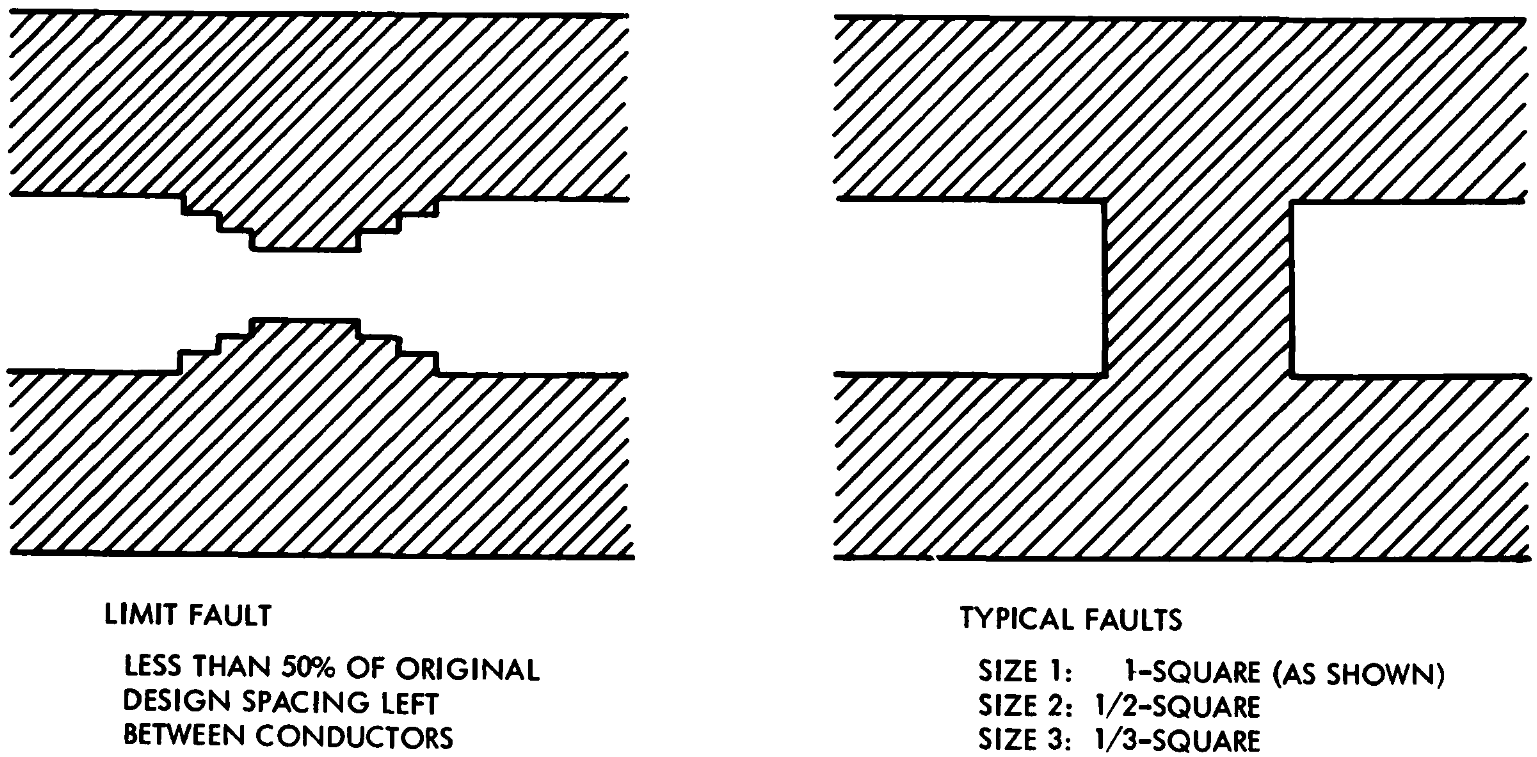


Figure 2-5. Fault Designs: Shorts and Whiskers between Conductors

2.1.1.2.3.4 Narrow Conductors

Conductors were made narrower than their design widths to 0.5-mil granularity by deliberate layout designs. All lines of a given pattern were reduced by the same amount. Taking advantage of the right-hand and left-hand symmetry of each pattern to increase the number of combinations, the distribution of the various narrow lines was as follows:

Pattern No.	Fault Design Line Width (mils) LEFT	Fault Design Line Width (mils) RIGHT	Normal Design Line Width (mils)
1	3.5	3.0	4
2	2.5	2.0	4
3	4.0	3.5	5
4	3.0	2.5	5
5	7.0	6.0	8
6	5.0	4.0	8
7	8.0	6.0	10
8	5.0	4.0	10
9	3.0 & 4.0	2.5 & 3.5	4 & 6
10	2.0 & 3.0	1.5 & 2.5	4 & 6

"Although screens were generated for these patterns, printing difficulties were encountered in achieving consistant line widths for the very narrow conductors."

2.1.1.2.3.5 Wide Conductors

Conductors were made wider than their design to 0.5-mil granularity by deliberate layout design. All lines of a given pattern were increased by the same amount. Taking advantage of right-hand and left-hand symmetry to increase the number of combinations, the distribution of various wide lines is as follows:

Pattern No.	Fault Design Line Width (mils) LEFT	Fault Design Line Width (mils) RIGHT	Normal Design Line Width (mils)
1	4.5	5.0	4
2	5.5	6.0	4

Pattern No.	Fault Design Line Width (mils) LEFT	Fault Design Line Width (mils) RIGHT	Normal Design Line Width (mils)
3	6.0	6.5	5
4	7.0	7.5	5
5	9.0	10.0	8
6	11.0	12.0	8
7	12.0	14.0	10
8	15.0	16.0	10
9	5.0 & 7.0	4.5 & 9.0	4 & 6
10	6.0 & 8.0	6.5 & 10.0	4 & 6

2.1.1.2.3.6 Scratches

Scratches occur in practice from careless handling. Use of sharp probes for continuity tests and resistor-value measurements is common. If the probe slips, it can gouge the material. Scratches caused by probes would be on fired (not dried) material. Scratching of dried material would be caused more typically by someone's use of metal tweezers in handling a thick-film substrate in the dried or fired state. Normally, substrates are handled manually by personnel using finger cots or plastic tweezers, so damage by tweezers is uncommon in a controlled production environment. Another possible source for scratches of film, either dried or fired, is the dragging of one substrate (especially its corner) over another.

Scratches of conductors on the demonstration substrates were simulated manually with real tools and even the corner of another substrate. To the extent practicable, these faults were "expertly" made by hand and the results documented in a quantitative fashion. "Limit" faults and "typical" faults were located and distributed in a manner similar to that outlined for opens (para. 2.1.1.2.3.1) and shorts

2.1.1.2.3.7 Mislocated Lines

Once a design is confirmed, the only way lines can get mislocated is when they are printed; and then all lines of the pattern are mislocated together with respect to the substrate referenced axis. Demonstration substrates were made by deliberately misaligning plates using the adjustable vernier controls of the printer. Thus all ten patterns were displaced by the same amount in the same amount in the same direction as follows during the conductor printing:

Sample No.	Displacement (mils) X	Y
1	2	0
2	4	0
3	6	0
4	0	2
5	0	4
6	0	6
7	1	1
8	2	2
9	4	4
10	6	6

2.1.1.2.3.8 Smeared Lines

Semaring is a defect ocurring during printing when the inks are still wet because of accidents in handling. Much like the case for scratches, these faults were introduced manually on wet conductor ink to simulate varying degrees of smears and the results documented quantitatively. These different degrees of smearing faults were distributed among the 10 patterns without any special concern relative to the line widths and spacings.

2.1.1.2.3.9 Combinations of Conductor Faults

Different practical faults were designed by layout or manually produced to simulate opens (voids), shorts and whiskers, no-print, scratches and smears. No meaningful new information appeared to be realized by including combinations of narrow and wide conductors and mislocated conductors with the other faults. Therefore, these gross-type faults were not included for the so-called "combination"- fault substrates. Combination faults were distributed randomly among all 10 different patterns.

2.1.1.3 Substrate Alignment Considerations

This paragraph is included in the defects analysis because it provides a basis for considering "real-world" printing alignment capabilities and practices in relation to alignment allowances of MIL-STD-883.

2.1.1.3.1 Practical Production Printing

Limited data taken on RCA-AS printed substrates revealed the following:

a. Maximum deviation of the average location of a given line in a production lot with respect to its location as designed, 1 to 2 mils.

b. Standard deviation for the location of a given line in each specific lot with respect to its average location in that lot, 0.5 to 1 mil.

2.1.1.3.2 Specific Requirements in MIL-STD-883, Method 2017

This specification gives very little guidance relative to thick-film alignment.

a. Para. 3.1.3.1(h) - Reject "substrate that does not have 50% of the origninal design separation between operating metalization and the edge of the substrate". AS hybrids usually are designed to have a 10 mil separation between a conductor and substrate edge; therefore, misalignment of the conductor up to 5 mils would be acceptable.

b. Para 3.1.3.2.8 - Metalization alignment. This paragraph is applicable to thin film, but not thick film hybrids.

2.1.1.3.3 Pratical Alignment Rules

Reject substrates for misalignment of conductor metalization by more than 50 percent of the minimum spacing between conductor layers.

Example: For 10 mil line spacing, reject if metalization is misaligned by more than 5 mils; for 5-mil line spacing, reject if metalization is misaligned by more than 2.5 mils.

2.1.2 Illumination Analysis

A hybrid circuit assembly or "hybrid" comprises a ceramic substrate (alumina) on which are deposited various combinations of gold conductors, gold/platinum conductive pads, dielectric layers and film resistors. The various elements are applied in successive layers by screening processes and are relatively rugged and durable when fired. The substrate is hard, abrasive and durable. Thickness generally ranges from 20 to 30 mils. Maximum size of substrates required to be accomodated by the AIME system, without repositioning, is two inches by two inches.

2.1.2.1 OPTICAL PROPERTIES

2.1.2.1.1 Substrate

The alumina substrate is white and translucent with a substantial amount of internal scattering. Effective reflectivity is approximately 70% if the supporting surface is aluminum and 50% of it is non-reflective. Substrate reflection is approximately Lambertain with no evidence of sheen or other directional properties.

2.1.2.1.2 Dielectric

The dielectric layers are white translucent and barely distinguishable from the substrate. The mesh of the screen commonly used to deposit the dielectric is 200 per inch, resulting in a distinguishable (with magnification) but low contrast pattern. Some sheen is present at grazing illumination angles.

2.1.2.1.3 Gold Conductors

The gold conductors are screened with a mesh of 325 per inch and the granularity is clearly visible. Despite the graininess of the surface, a strong specular component of relfection is apparent, even at near perpendicular illumination and observation angles.

For perpendicular observation and near perpendicular illumination, the reflectivity exceeds that of the substrate. As illumination direction departs from the normal, the reflection from the gold decreases until, at 45° the gold reflectivity is substantially less than that of the substrate (See Figure 2-6).

Where covered by dielectric, the gold, although dimmer is still clearly visible, but the dielectric scattering eliminates the directional properties of the gold reflectivity.

2.1.2.1.4 Platinum - Gold Pads

Like the gold, these conductors are screened at 325 per inch. However, they show little if any directional reflectivity. The color is gray, indicating uniform spectral response in the visible (and RBV) range.

2.1.2.1.5 Resistors

The resistors are very low in reflectivity with a slight sheen which makes the screening pattern, a mesh of 200 per inch, visible. Even the highlights are much lower in reflectivity than any of the other materials.

2.1.2.1.6 Backside Metallization

About 50% of the hybrids are metallized with gold-platinum, over the entire rear surface, in a pattern of squares and rectangles. Typically the squares are spaced twenty to the inch and the rectangles are slightly longer in one dimension. The blank lines between the squares are about .007 inch in width.

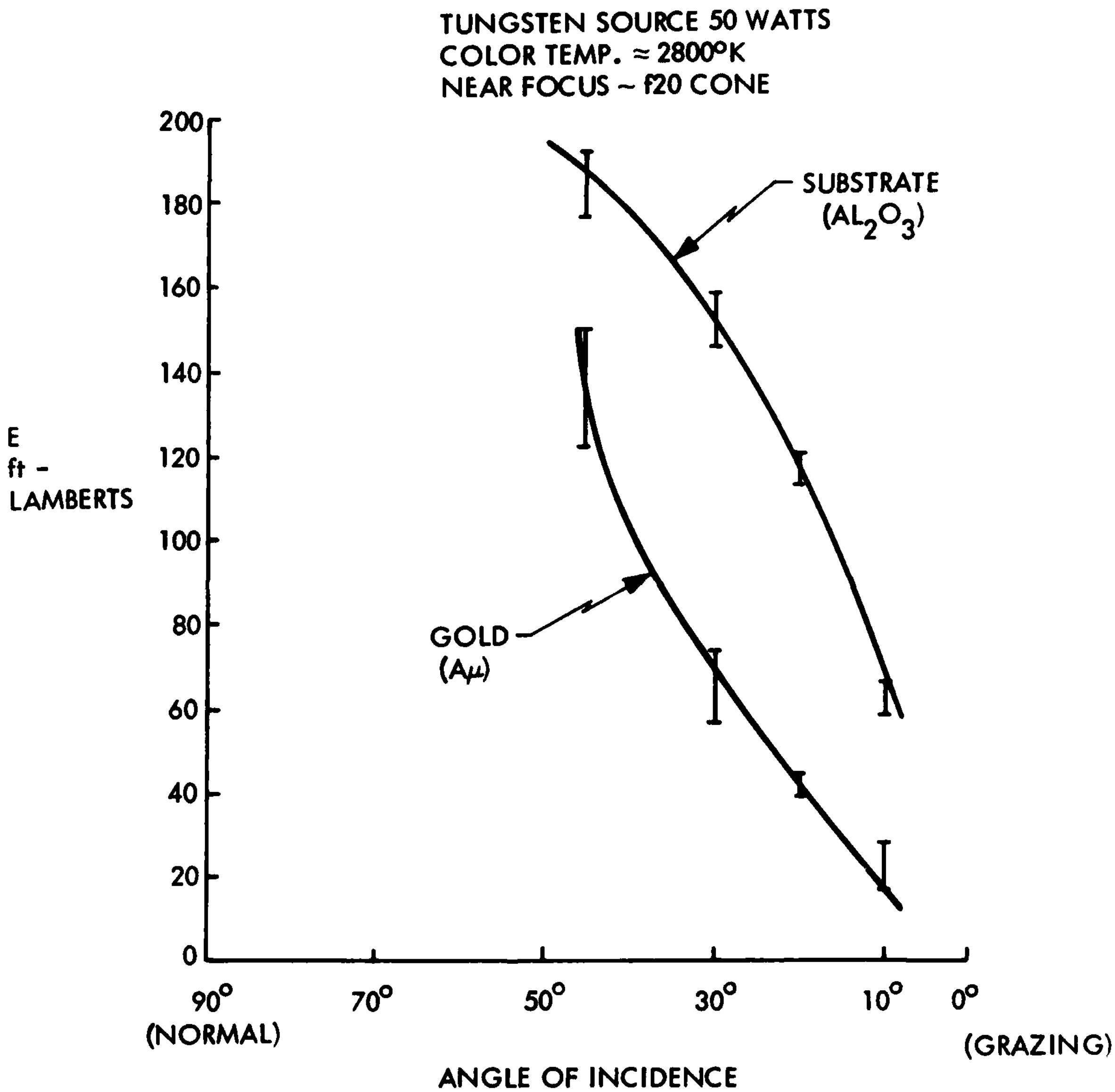


Figure 2-6. Hybrid Luminance

With the substrate back-illuminated, there is considerable blurring of the pattern, caused by scattering in the substrate. The attenuation of light caused by the reduction of area is approximately 4:1. Transmission of the substrate alone, for 30 mil thickness with diffuse illumination is 36%. Tests have shown that that high contrast between gold conductors and film resistors, and that of the substrate can be achieved with back-illumination in spite of the backside metalization.

2.1.2.2 Sensor Spectral Response

Figure 2-7 shows a representative relative spectral response for the Antimony Sulfi-oxy Sulfide ASOS surface employed in the 4.5 inch RBV tube. Also shown for comparison is the standard photopic response for human vision. From the curves it can be seen that visual observations of hybrid photometric properties correspond reasonably well with the RBV responses.

2.1.2.3. Illuminator

2.1.2.3.1 Spectral Properties

Figure 2-8 shows the approximate spectral properties of tungsten halide incandescent lamps at color temperatures of 3000°K and 2350°K respectively. The former represents the normal operating condition for maximum output and rated lifetime of 50 hours, while the latter represents a reduction of luminous output by a factor of ten to one. This would be accomplished by lowering the lamp voltage to 50% of rated value (a current of 70% of rated value). It results in a pronounced red shift in the peak response and a sharp reduction of the green-blue regions of the spectrum.

In addition to altering the spectral content of the lamp, reducing the voltage may cause the halogen cycle to cease functioning thereby permitting evaporation tungsten to be deposited on the lamp envelope. For these reasons, other means of varying the illuminator output have been explored and will be discussed below.

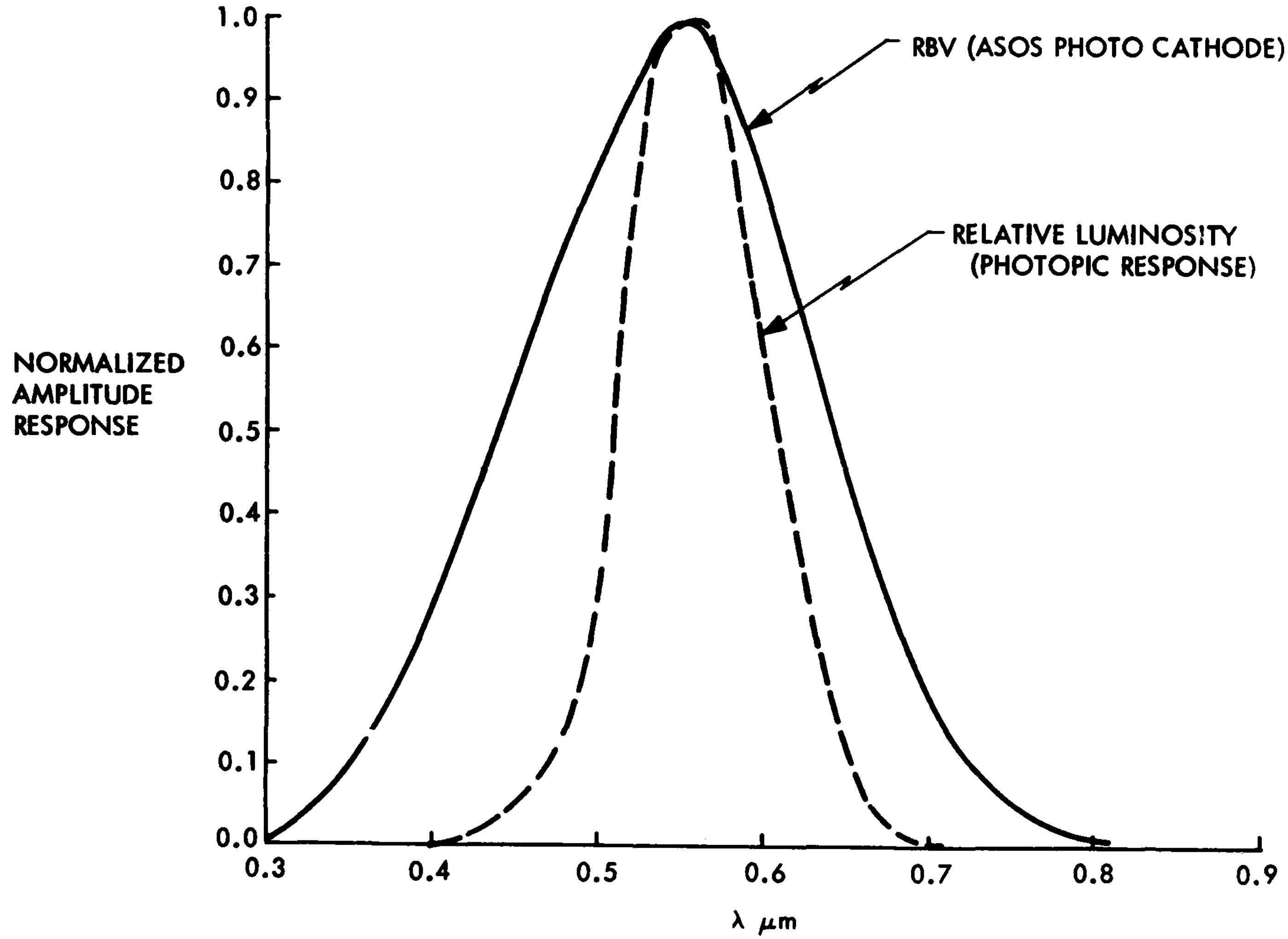


Figure 2-7. RBV Spectral Response

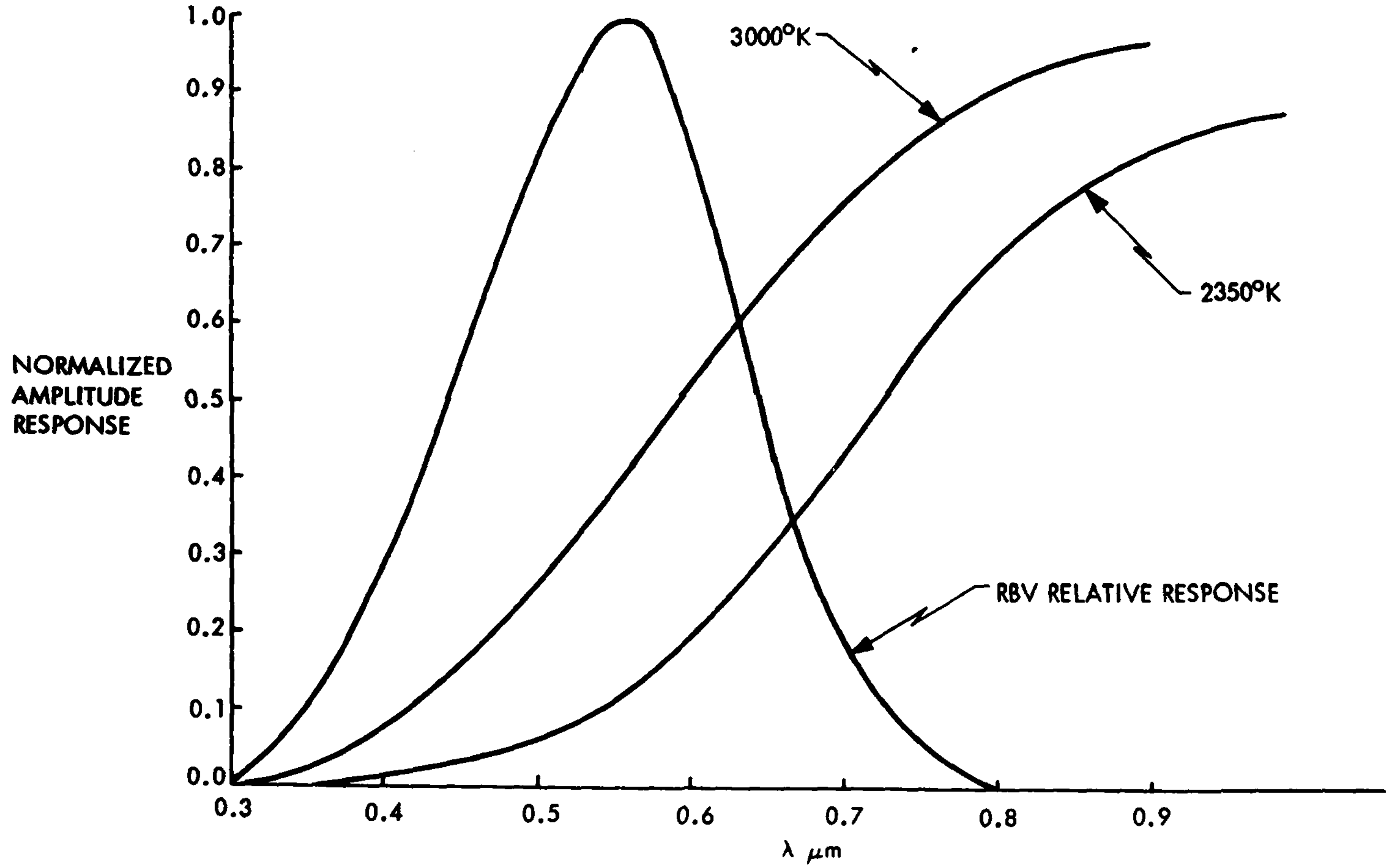


Figure 2-8. Illuminator Spectral Content

2.1.2.3.2 Use of Iris for Attenuation

To improve efficiency and eliminate the annoyance of scattered light, a housing, shown in Figure 2-9, and a condensing lens are required. The lens tube also provides a convenient mounting for an adjustable iris, which, placed close to the lens aperture, will attenuate the illuminator output without vignetting the illuminated area. By this means attenuation ratios of greater than 100:1 can be obtained without any change in the lamp spectral properties.

The tube also provides a mounting for a "hot mirror" and for spectral filters if necessary. The former can reduce the heat output of the illuminator by at least 60% and the latter may be used for contrast enhancement.

Other means of varying the illuminance on the RBV tube face are neutral density filters, RBV lens iris adjustment (subject to depth of field requirements), and exposure time control, if the snapshot mode is utilized.

2.1.2.3.3 Spectral Filtering

As shown in Figure 2-6, there is a good contrast between gold and the aluminum oxide substrate for tungsten illumination at obtainable angles of incidence*. Figure 2-10 shows the relative spectral responses of the ASOS (RBV) photo-surface, the 3000°K tungsten source and the reflectivity of gold. Figure 2-11 shows the resulting system response to the gold conductors and to flat spectrum surfaces such as the alumina substrate.

2.1.2.3.4 Back Illumination

Although back illumination would increase the contrast, relative to the substrate, of all deposited materials except the dielectric layer, there would be no contrast of gold versus the resistors. The front contrast of gold, and carbon relative to the substrate is good, but the adequacy of Signaltonoise S/N for automatic processing is marginal. At this time is appears that back illumination is the preferred approach for disposition inspection.

* Note that angles above 30 degrees are precluded because of interference with the RBV and lens assemblies. If a shutter is used, to implement the "snapshot" mode, angles above 20 degrees are precluded.

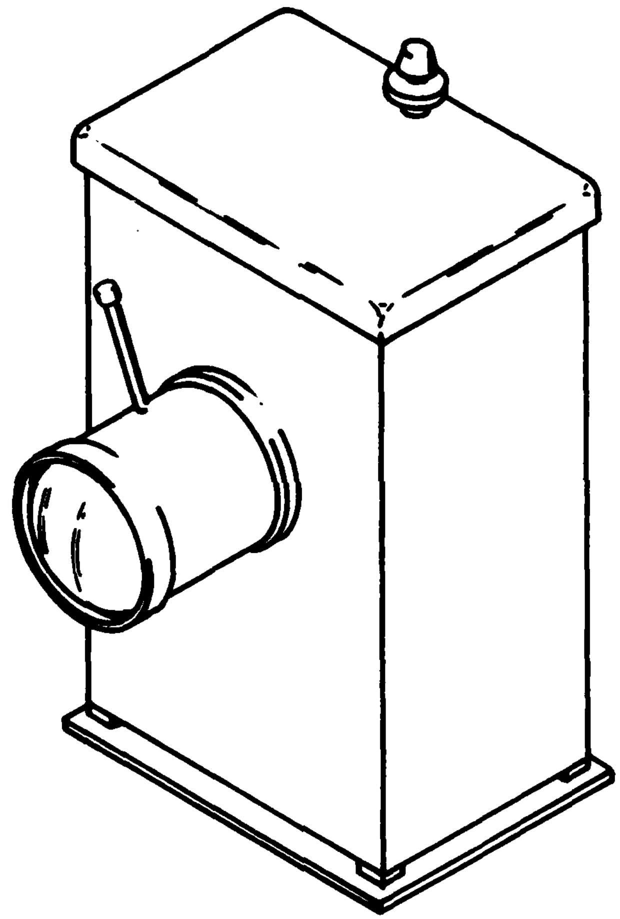


Figure 2-9. Lamp Housing with Condensing Optics Assembly

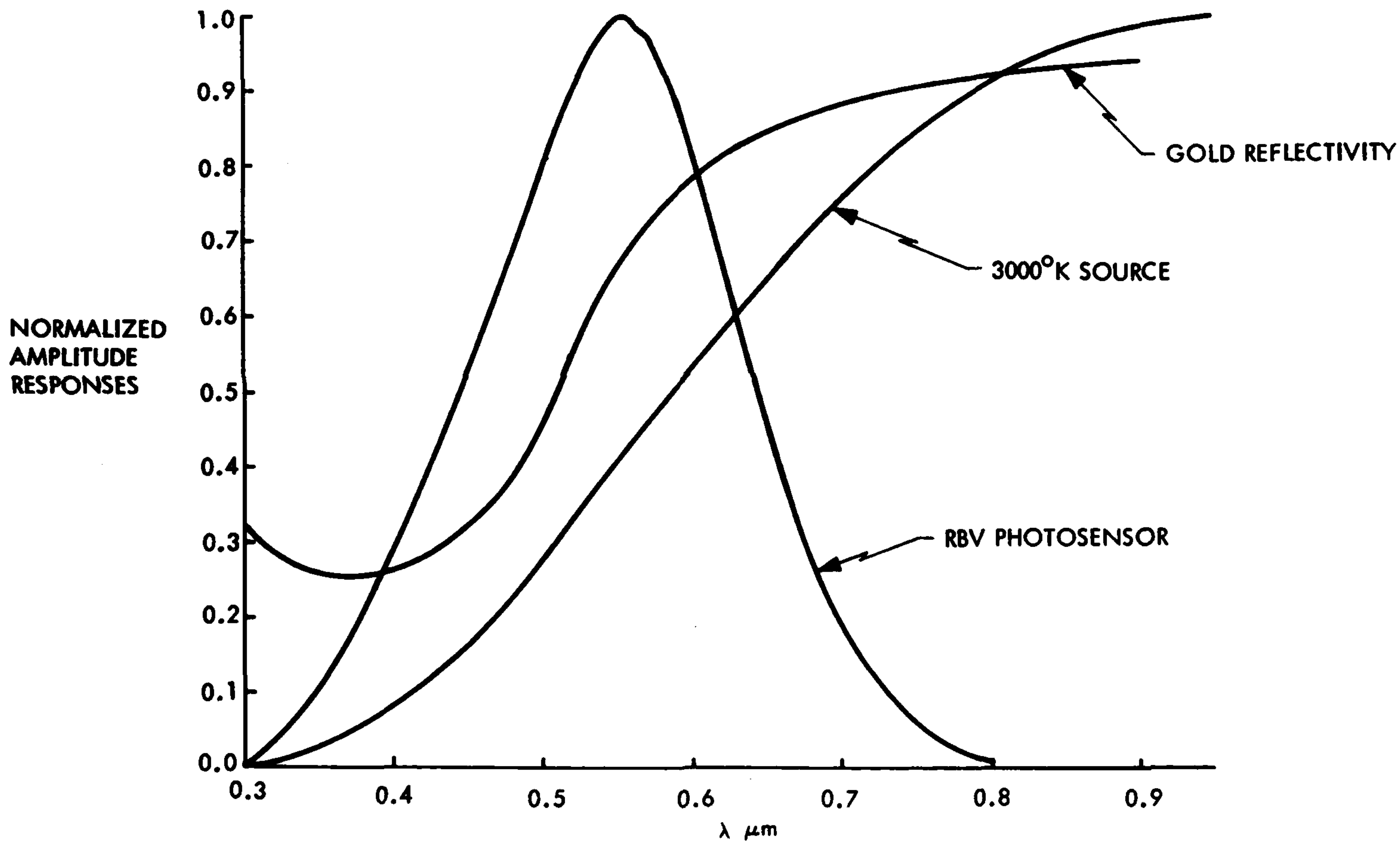


Figure 2-10. System Spectral Characteristics for Gold Conductors

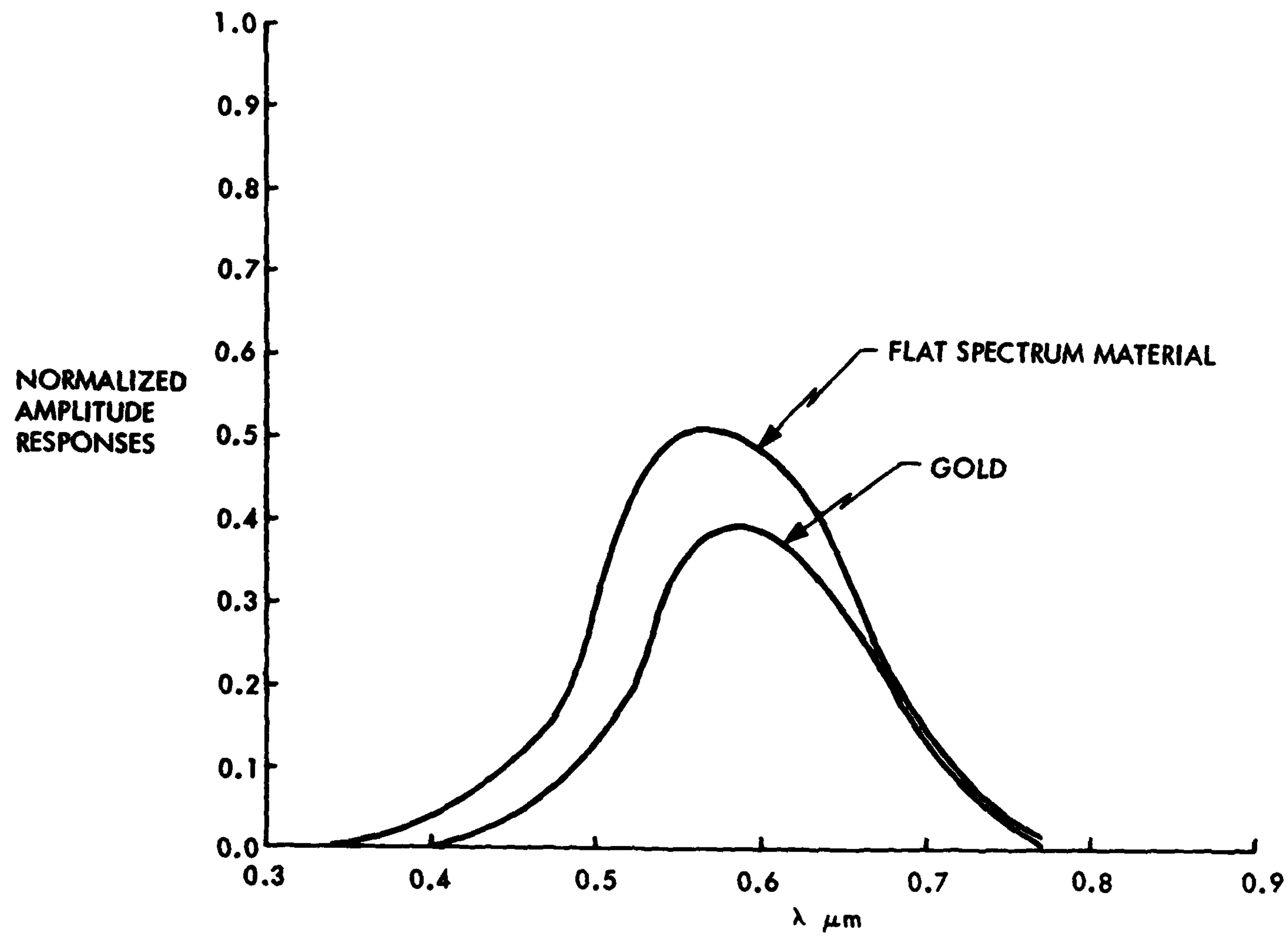


Figure 2-11. System Relative Responses

2.1.2.3.5 Reduction of "Graininess"

Owing to the screens used in depositing the layers, the surfaces appear rough under magnification and the local reflectivity varies, as shown in Figure 2-6 (for a single illuminator). Examination shows that some or most of this variation is caused by shadowing in local depressions having dimensions corresponding to the mesh spacing. To minimize these shadows for frontal illumination, two illuminators were symmetrically located relative to the center of the hybrid mounting surface of the substrate.

2.1.2.3.6 Illumination Geometry

The hybrid can be illuminated by focussed, collimated or divergent light but the substrate size, 2 inches by 2 inches, would necessitate an unusually large illuminator aperature (about 3 inches diameter) if collimated light were to be used.

Of the two remaining methods focussing is the more efficient in that the lamp filament area is directly imaged onto the hybrid. To avoid local variations due to the image of the filament wires, a defocussing distance of about 0.5 inch is required.

The lamp of Figure 2-9 is designed for focussed or imaging illumination in that the filament is closely coiled so as to produce a nearly solid source area.

Since the source is rectangular, there is only one angle of incidence at which the source image matches the square substrate, about 33° for the lamp dimensions.

Figure 2-6 indicates that maximum reflectivity ratios are obtained for incidence angles between 10 and 30 degrees, with luminance decreasing steeply as incidence decreases.

Accordingly an angle of 20 degrees, representing the limit due to shadowing by the RBV camera shutter housing, was chosen.

Allowing for variation of the illuminator condensing lens focal length and for non-uniformity in the edges of the defocussed beam, a distance of 20 inches from the condensing lens to the center of the substrate assures that the filiament image plane approaches no closer than 0.5 inch from any point on the substrate, and the substrate lies within the region of the beam.

With these dimensions, the illuminance on the substrate can be estimated for two illuminators of Figure 2-9, to be 4800 lumens/square foot. Reflectivity is at least 50% so the resulting luminance is 2400 ft. lamberts. The nominal requirement is 114 ft. lamberts with the RBV lens set at f8 and operating in the continuous mode. A margin of 21:1 is therefore left for any spectral filtering which may be employed.

2.1.2.4 Conclusions

The illumination requirements for the demonstration AIME system were established. The requirements were based on a study of different types of illumination and the effects on the resulting contrast between gold conductor lines and film resistors, and the ceramic substrate. The positioning of the illumination source was established. The conclusion of the analysis was as follows:

(1) A Quartz-Halogen (color temperature of 3000°K) was selected.

(2) Three illumination source units were used as follows:

- Two units positioned to illuminate the conductor or top side of the UUT
- One unit to illuminate the non-conductor or back of the UUT

(3) The angle of incidence of the top illuminators is 20°.

(4) The lamp housing provides a mounting for spectral filters if necessary to obtain better contrast.

It should be noted that, although a back illuminator is being provided, its usage could be constrained by the fact that some substrates have a gold-platinum metallization over the entire back surface. The pattern over the back is, typically, a series of squares or rectangles. This pattern along with the substrate, greatly attenuate the total transmitted light as well as introduce a "modulation" on the transmitted light.

Also, based on a comparison of the RBV spectral response and the standard photopic response for human vision, it can be concluded that the RBV "sees" what the human eye sees.

2.1.3 Alternate Hybrid Inspection Techniques

An investigation into possible alternate hybrid inspection techniques was undertaken. The one possible method suggested is a lasar differential line scanner (LDLS). This method is presently being used to inspect transparent objects which have a repetitive matrix of patterns (such as masks or SOS wafers). A reflective light system could be configured, but several disadvantages would exist:

LDLS Operation:

The LDLS can test transparent objects (such as masks or SOS wafers) which have a repetative matrix of patterns. The incident laser beam is split and aligned to scan identical areas of adjacent patterns on the glass mask with a 525/60 TV raster of 24 mils width. The detectors are placed on the opposite side of the mask. The mask holding fixture is translated in X and Y to scan the full mask.

Conclusions:

Disadvantages of the presently configured LDLS are that it cannot inspect non-transparent object like hybrid circuits. However, a laser scanner could be configured to utilize a reflected light detector but the system would have certain disadvantages as follows:

a) Monochromatic laser light could not be color filtered to take advantage of spectral information in the hybrid.

b) It would be difficult to zoom the laser scanner as is done in the RBV electronics. Wise angle laser deflection for overall hybrid viewing can be accomplished with an acousto-optic crystal (horizontal) and galvonometer driven mirror (vertical) in conjunction with optics to increase the deflection angle. But narrow angle (zoom) viewing would require an optics focal length change.

c) Steering the laser beam to different parts of the hybrid would require accurate UUT fixture translation instead of the stationary hybrid fixture used by the RBV system which has electronic zoom steering.

d) Image non-uniformity (shading) may result from certain types of mechanical laser beam deflection because the scan velocity is not constant. The RBV has linear (constant velocity) scanning in horizontal and vertical.

2.1.4 High Speed Inspection Techniques

The AIME system demonstrated the feasibility of using the high resolution RBV to image an entire substrate and produce sub-images for evaluation by means of electronic zoom and steering. Continuous 525 TVL readout with steady state exposure was used since a standard rate display, time base corrector and video recorder could be used for demonstration. High speed operation for complete substrate evaluation at rates of 750 substrates/hour, however, cannot be achieved with this mode.

The 750 substrate/hour requirement can be achieved by operating the RBV camera in a "Snap Shot" mode. The timing diagram in Figure 2-12 illustrates the timing sequence using a controlled shutter exposure followed by sequential readout of 33 discrete image areas selected from the stored image on the RBV target. After readout of the entire substrate image in 1.1 sec., the target is then prepared by an erase and prime cycle for the next exposure while a second hybrid UUT is positioned prior to exposure. The entire cycle is completed in 4.8 sec. and is compatible with the data handling rate of the computer for image analysis.

2.1.5 AIME Misregistration Error Budget

2.1.5.1 Background

Due to normal production tolerance of hybrid circuit assemblies, some misregistration between the reference image and the UUT image would occur even if no errors were introduced by the system.

Each screen used in depositing circuit elements such as conductors, resistors, pads and insulators, is aligned by reference to two edges of the substrate. Worst case displacement of any screen relative to any other is 2 mils. Error due to placement of the substrate in the UUT holder is negligible compared to the screen registration errors.

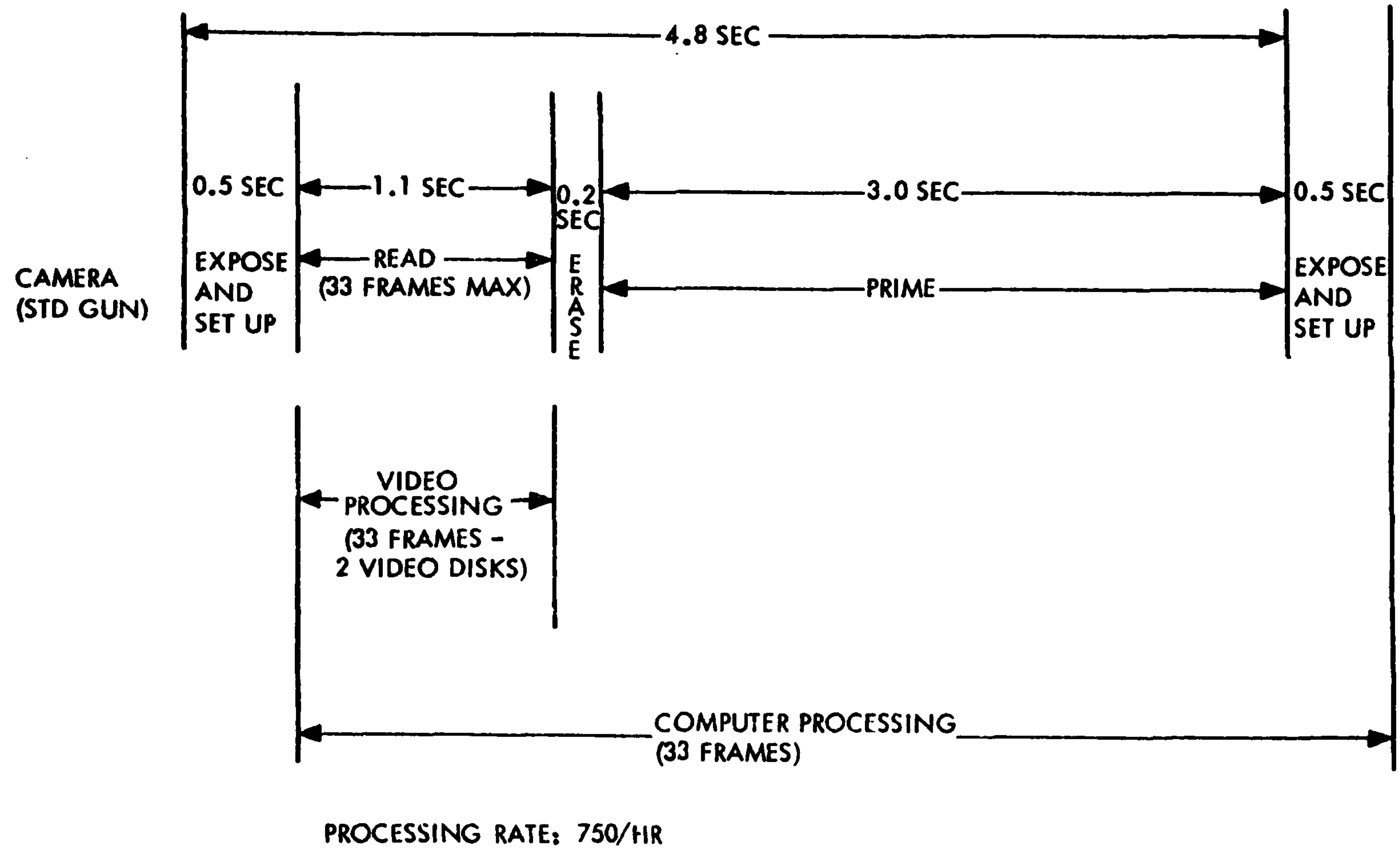


Figure 2-12. AIME Snap Shot Mode Timing

In addition to the systematic errors above, the edges of the deposited materials, viewed under magnification, are ragged to the extent of about 1 mil maximum span.

The minimum width of the conductors is 5 mils, with 10 mils much more common. In either case, allowable errors (i.e. errors which should not cause a UUT to be rejected) between the referenced image and the UUT image must be masked out. This will be done in the computer analysis by excluding all data in strips along the edges of the circuit elements as shown in Figure 2-13.

If these strips were widened to allow an additional guard band of two or more lines (or pixels) then a substantial misregistration could be allowed without generating false errors by causing the element image edges to move out from under the computer mask. From the numbers given above, however, and assuming that a reference image is generated from an unusually accurate substrate, the mask strips would need to be 5 mils wide to exclude any chance of false rejection of a UUT. A mask of these dimensions would obliterate all 5 mil conductors and leave only 5 mils of a ten mil wide conductor. In the former case all ligitimate defects would be masked, while in the latter all fatal defects would be detected together with some non-fatal ones such as voids which do not extend very far under the mask.

It is reasonable to assume that, if 5 mil conductors are used, placement and width will be more accurate than the tolerances given above. Furthermore the edge raggedness will be reduced by the use of finer screen mesh, probably halving the tolerances given above.

2.1.5.2 Criterion

To avoid degrading the fault detection situation described above, while allowing an achievable level of system errors, an achievable level of system errors, an additional allotment of ± 1.0 mil placement error is required to accomodate system errors.

2.1.5.3 System Error Budget

Table 2-2 lists the system contributors to registration errors, many of which are minimized by the system design.

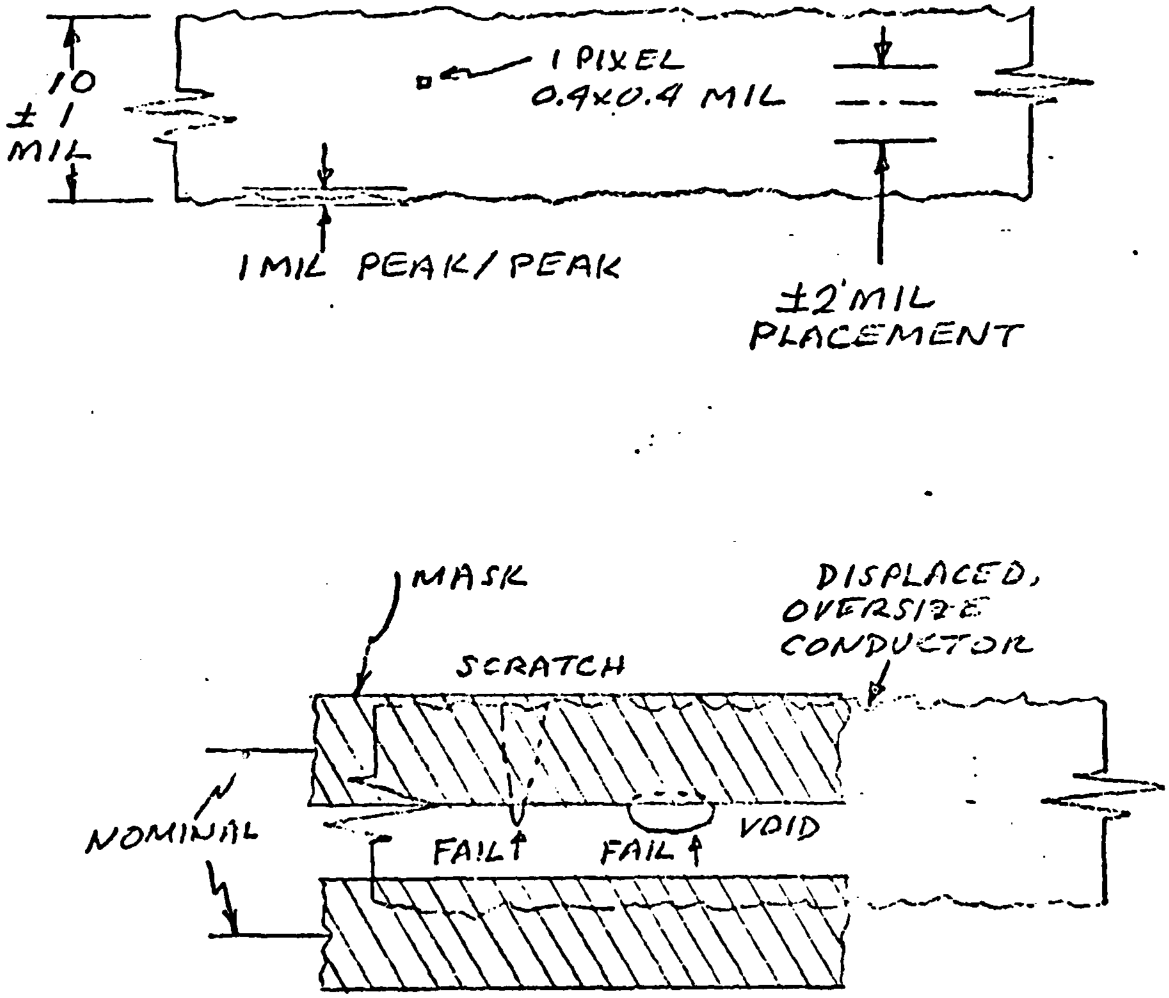
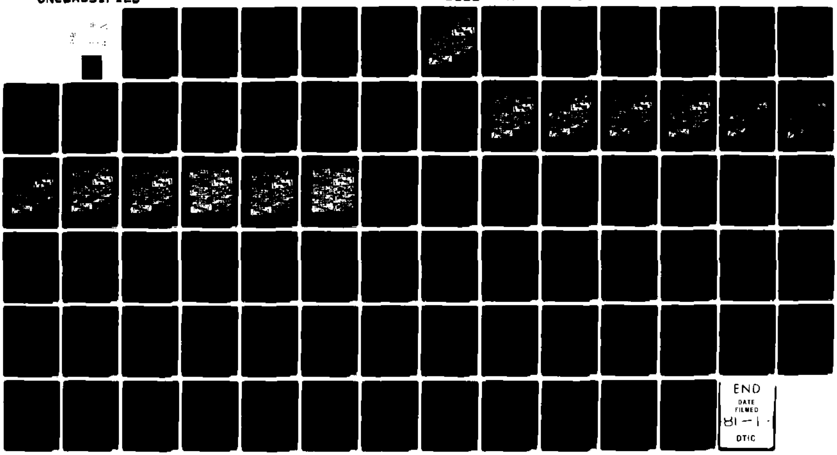


Figure 2-13. Geometry of Circuit Element Tolerances and Edge Mask

AD-A091 854 RCA AUTOMATED SYSTEMS DIV BURLINGTON MA F/G 14/2
MANUFACTURING METHODS AND TECHNOLOGY PROGRAM AUTOMATIC IN-PROCE--ETC(U)
OCT 80 R J WILDENBERGER, J M LASKEY DAAB07-77-C-0585
UNCLASSIFIED DELET-TR-77-0585-F NL



1.0 2.8 2.5 3.2 2.2 3.6 4.0 2.0 1.1 1.8 1.25 1.4 1.6

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Hybrid Circuit Production Tolerances

Magnetic Field Effects on Camera Deflection

Mechanical and Thermal Displacement of UUT, Lens and Camera Image Plane

Raster Offset Circuit Variations

Camera Accelerating Voltage Variations

Camera Sweep Circuit Variations

Recorder/TBC Residual Jitter

Camera Chain/Recorder Chain Differential Delays

Sync Generator Temporal Errors

Connecting Cable Differential Delays

Table 2-2. Registration Error Source

2.1.5.3.1 Magnetic Fields

Magnetic field effects are reduced to tolerable levels by shielding and cable routing. Earth field effects are cancelled by recording a new reference image if a change of location of the camera has been made.

2.1.5.3.2 Mechanical Thermal Displacements

Mechanical displacements of parts are minimized by rigid mechanical construction, isolation of the camera from floor vibrations by means of an air suspended table, and decoupling of air conditioner vibrations. For thermal deplacement, provision is made for translational and anglular adjustments appropriate to setup at the beginning of a test run. Final design for a production test system would include use of similar metals and thermal compensation, if necessary, in the structure connecting UUT holder, lens and camera. A residual shift of ±0.25 mil on each axis for ± 10°C temperature change is allowed for this error source. Techniques for thermal compensation of precision alighment structures were developed on the LCSS program.

2.1.5.3.3 Raster Offsetting Circuit Variations

In the 10:1, maximum resolution, zoom mode, the offsetting circuits are required to position the camera raster center to a precision of well under one pixel where the pixel dimensions are defined by the scan line to scan line dimensions of 0.42 mils on the vertical axis and by horizontal resolution limits, nominally the same, on the horizontal axis. To accomplish this, it is desirable that the chain comprising the analog to digital converter, the deflection drive amplifiers, the camera deflection coils and the beam accelerating voltage maintain precision over a temperature range of ± 2°C for a period of at least 1/2 hour for the feasibility model and ± 10°C for an 8 hour test run for a production model.

The selected DACON is represented by the vendor as capable of 2.5 ppm/°C or less and repeatability of ± 30 ppm of full scale range (the purchased 12 bit unit is stated to have the same repeatability as the 16 bit, more expensive, unit). The repeatability error will be eliminated along with mechanical positioning errors discussed above by setup at the beginning of a test run, leaving ± 2.5ppm variation of full scale range due to temperature

changes. Camera deflection sensitivity in the vicinity of sharp contrast changes is aggravated by beam bending or pulling and has been measured at 1/3 TV line or 0.14 mil for 150×10^{-6} of full scale deflection signal. The resulting center position variation for raster locations in the corners of the 2" x 2" format is:

$$2'' \times (+ 25 \times 10^{-6}) \times \frac{.14}{150 \times 10^{-6}} = \pm .05 \text{ mil}$$

on each axis. An additional equal allowance is provided for the operation amplifiers which accept current feedback from the deflection coils. Current pickoff and summing resistors (3 total) at 5 ppm/°C tracking error account for .15 mil in the feasibility model so even better temperature coefficient tracking, or temperature control, will be required for production model. The total budget for the centering (or steering) circuits is then ± .25 mil for a production system.

2.1.5.3.4 Camera Accelerating Voltage Variations

Addition deflection errors are introduced by variation of the beam accelerating voltage. They are proportional to the product of fractional change of voltage and the displacement (offsetting) of the raster. This voltage has been observed in the laboratory environment to vary by 0.01% or less over a 1/2 hour period. The resulting deflection error for raster positions in the corners of the 2 x 2" format are ± 0.2 mils. To maintain this repeatability in a production model will require improved regulation and possibly temperature control of the voltage reference.

2.1.5.3.5 Camera Sweep Circuit Variations

Because the sweep deflections are only one ninth the maximum displacement of the raster (± .1 inch vs. ± 0.9 inch) the errors in repeatability of the sweep can be considerably larger. A value of ± 0.1% would yield (reasonable) errors of ± 0.2 mils.

2.1.5.3.6 Recorder/Time Base Corrector (TBC)/Sync Generator Residual Jitter

The residual TBC jitter of ± 2ns or less produces position errors which are negligible relative to other sources. Synch generator jitter of ± 4ns is also negligible.

2.1.5.3.7 Camera/Chain Recorder Chain Differential Delays

Fixed delay differences are compensated, if necessary, by offsetting the TBC output. Frequency variable delays are compensated in the video amplifier chain.

2.1.5.3.8 Interconnecting Cable Differential Delays

Cable length is matched, as appropriate, to reduce these errors to negligible size.

2.1.5.4 Error Budget Summary

Table 2-3 summarizes the registration error budget. Cumulative values are obtained by adding rather than root sum squaring the various errors because the probability of exceeding the allowance even at one point is required to be quite low (5% or less is reasonable) over an entire substrate.

2.2 HYBRID SAMPLES

The hybrid sample substrate provided for test and evaluation on the AIME demonstration system contains 10 patterns each as shown in Figure 2-14. There are 2 patterns each of 4, 6, 8, and 10 mils line width and 2 patterns which contain a mixture of 2, 4, 6, 8, and 10 mils line width. Appendix A contains the 12 sample substrates containing defects which were used for data gathering and evaluation.

2.3 FINAL SOFTWARE DESIGN

The final software design was completed and validated by mid December, 1978. The AIME system software consists of the Data General Real-Time-Disc-Operating system (RDOS), the Command Line-Interpreter (CLI), the AIME Run-Time System, and various utility programs.

	Feasibility Model	Production Model
Operating Conditions		
Temperature	Laboratory (±2°C)	±10°C
Duration of run	0.5 hour	8 hour
Error Source (Mils)		
Mechanical Displacement	±0.3	±0.25
Raster Offset Circuit	±0.25	±0.25
Camera Accelerating Voltage	±0.2	±0.2
Camera Sweep Circuits	±0.2	±0.2
Total (Worst Case)	±.95 mil	±0.9 mil
Production Tolerances		
10 mil conductors	±2.5 mil	±2.5 mil
5 mil conductors (estimate)	±1.5 mil	±1.5 mil

Table 2-3. Summary of System Registration Errors

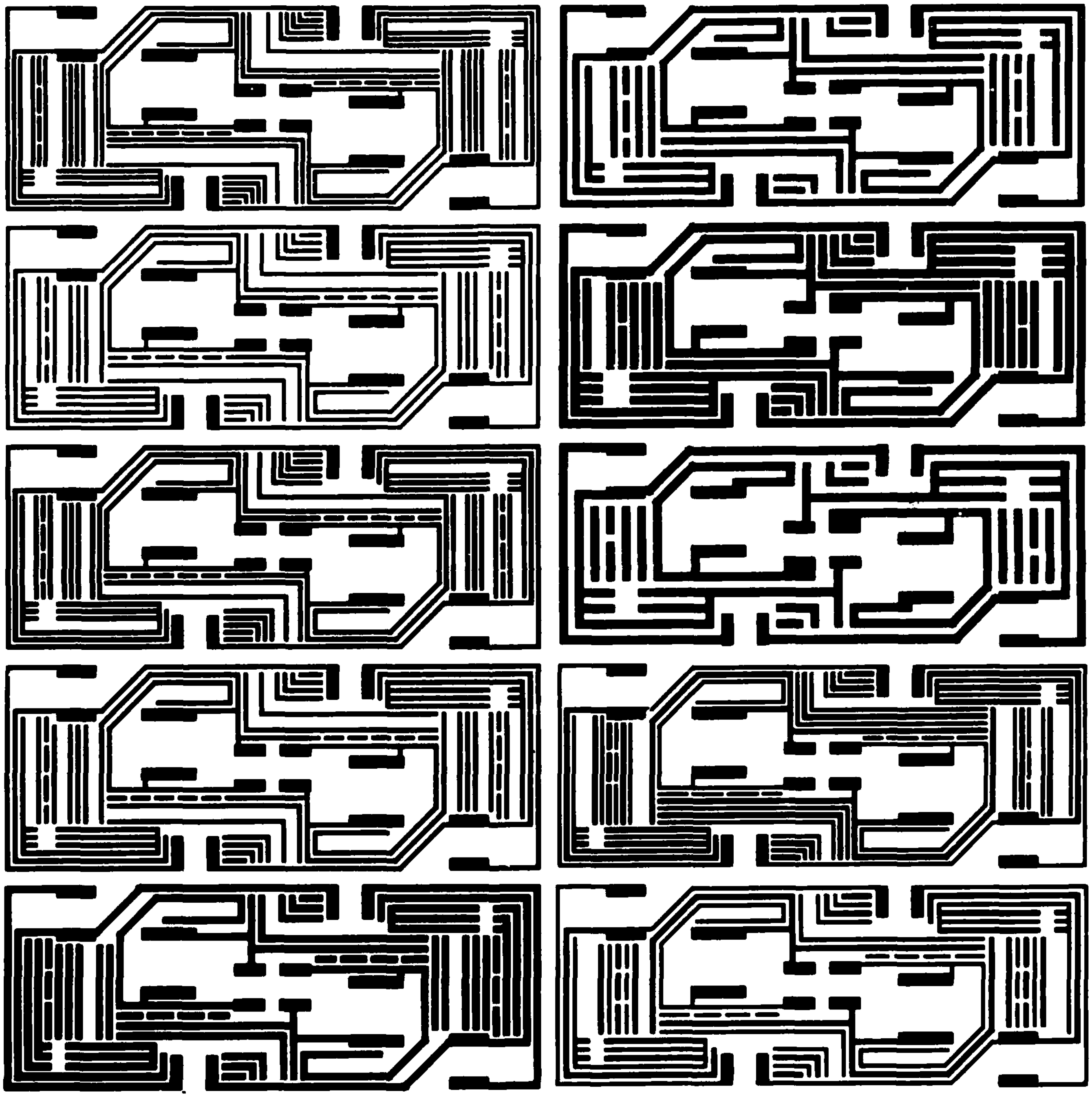


Figure 2-14. Sample Substrate Used As Evaluation Model

Real-Time-Disc-Operating System (RDOS) and CLI

RDOS is a comprehensive and flexible operating system normally used with disc-based NOVA systems.

The command Line-Interpreter (CLI) is a dynamic interface to RDOS via the console and translates the input as commands to the operating system.

Run-Time System

General

The AIME Run-Time System (ARTS) performs the functions of program generation, and test execution. It is written in a high level language (ALGOL) utilizing structured programming techniques to obtain modularization for ease of maintenance and understanding. Assembly language modules are minimized and used only where necessary for speed or special-purpose programming such as required in image processing.

Program generation an be accomplished either on-line or off-line. On-line program generation allows the user to try various setups for X-Y positions, zoom, illumination, etc. When a specific test setup is decided upon, the system software will remember, on operator command, the exact setup and will place the test setup in sequence with respect to other tests contained in a source file listing.

Test Program Generation

The test program generation is used to create automatic and semi-automatic test programs for substates and pre-cap hybrids respectively. The operator can activate and control the system from the keyboard. Sectors have been designated for the user in positioning the sub-images on the monitor. The higher the zoom ratio, the greater the number of sectors. Sectors are square in shape and are numbered from left to right and from the top down. When a suitable image is seen on the monitor the operator initiates the following system actions: (1) Interrogation of all system status registers, and storage of the current setup

data for the image, (2) the generation of a set of commands and related setup data, which when executed at a later date will result in the exact same setup conditions, (3) indexing and storage of the image on the video disc-recorder, (4) the generation of a MASK of the current image for the automatic test program.

Mask Generation

The mask generator (software module MASKGEN) is used to generate a mask for each reference image operating in the automatic mode. Where an etch boundary exists, the mask consists of a block of 'Ø's with '1's elswhere. The width of the block of 'Ø's is of sufficient magnitude to mask out offset and registration errors. The resultant mask is read into the computer memory and "AND"ed with the difference video data. The resultant data are then ready for the image processing.

Image Processing

The image processing algorithm analyzes the masked video difference data to render a pass/fail decision on a substrate. In order to achieve the processing rate of 750 substates/hour, the following detection scheme has been developed. The masked difference data is stored in the computer as '1's and 'Ø's, where a 1 represents the presence of difference video and a Ø represents the lack of difference video. The difference data is divided into 16-bit blocks for image processing. The image is thus divided into (30) rows and twenty six (26) columns which results in a matrix of 780 clusters of data. If a cluster is composed entirely of '1's, this indicates that this entire area is composed of difference video, and therefore represents a defect. The computer processes all 780 clusters, and determines which cluster contains the highest percentage of '1's. This cluster is then recorded on the line printer as the defect location. It is recorded in terms of a row between 0 and 29 and column between 0 and 25, thus the location can be verified by observation on the monitor. Prior to the start of a test the operator enters the percentage of '1's which is to be considered a defect. This, in effect, provides the accuracy of measurement for the system and allows minor errors due to misregistration to be disregarded.

2.4 FINAL HARDWARE DESIGN

The final hardware design was integrated and validated during the third quarterly reporting period. The major components of the AIME demonstration system are:

(1) Control/Display Station

- Computer and Peripherals
- Video Processor and I/O Control
- RBV Electronics, Power Supply
- Sync Generator
- Time-Base Corrector
- Video-Disc Recorder/Reproducer
- Video Monitor
- Illumination Power Supplies

(2) Inspection Station

- RBV Camera Head with Lens
- Illuminators (Lamps)
- UUT Holding Fixture
- Optical Table with the Structure/Shroud Assembly
- Air Conditioner Unit

However, since that time the integration of the software and initial attempts to test substrates resulted in the discovery of minor logic defects in the hardware design. The logic defects which consists of an intermittent short and defective integrated circuit on the computer were corrected, and software integration and validation was continued and completed.

2.5 ACCEPTANCE TEST

The AIME acceptance test, conducted on 21 December 1978, demonstrated the AIME system in manual, semi-automatic and automatic modes of operation. Automatic testing of hybrid test sample substrates and semi-automatic testing of precapped hybrids were demonstrated.

Hybrid pre-cap inspection is performed in a semi-automatic mode with the operator visually observing the monitor and making the pass/fail decisions. For this mode the computer goes through the predetermined inspection steps in sequence, presenting, on the monitor, a view for the operator so that he can inspect the hybrid. The operator evaluates each view and

presses a pass or fail key on the keyboard. This step-by-step process ensures an orderly and thorough inspection of the hybrid without the use of a microscope.

2.6 DATA GATHERING AND EVALUATION

The data gathering and evaluation task was performed on the AIME system during the period of 24 March 1980 through 4 April 1980. For this task, twelve (12) substrates containing faults typical to those found in the manufacturing process were tested against a "Master" substrate. The substrate which was chosen as the evaluation model is shown in Figure 2-14. The line widths represented are 4, 6, 8 and 10 mils. Faults contained on the twelve (12) defective substrates include breaks in the printed path, exessive ink along a printed path, necking down or narrowing of the printed path and shorts between two printed paths. Appendix A contains a pictorial view of each of the twelve substrates evaluated. Also shown are the defects contained on each of the substrates.

For this evaluation, AIME was programmed to test the substrates in the zoom 10 mode of image magnification. In this mode of magnification the substrate is recorded or examined in 49 separate sectors. In addition, each sector is electronically subdivided into a 26 x 30 matrix of subsectors. Should a defect be detected, the row and column of the substrate containing the defect is printed on the AIME printer. In the event of multiple defects within a sector, the largest defect is reported. The data gathering and evaluation was performed in the following manner:

(1) At the start of testing each of the substrates was individually inspected by the test operator using AIME in the manual mode of operation. The defects detected by test operator were then recorded on a printed enlargement of the substrate layout.

(2) A defect free "Master" substrate was then recorded by AIME in the automatic mode and a "go-chain" test was made in which the recorded substrate image was compared with the actual "Master" substrate. This test verified the proper operation of AIME.

(3) Each defective substrate was then evaluated by AIME. AIME was programmed to operate in the automatic mode with the verification flag set so that the test operator could confirm the defect detected by AIME. Mechanical realignment of the substrate was performed during the test as required by the test operator to minimize misalignment between the substrate and the "Master" recorded image. The defects detected by AIME were automatically printed on the AIME printer and were also manually recorded by the test operator on data sheets.

(4) Each defect on a substrate was classified as to size. Three size classifications were used: 0-3 mils (small), 3-6 mils (medium), and greater than 6 mils. The defect size was noted on the data sheets. In this manner it was possible to subjectively judge the ability of AIME to detect different sized defects.

(5) Precap inspection of hybrid assemblies utilizing the display was useful in verifying the location and bonding of chips and placement of wire bonds. However, the integrity of the wire bonding and wire crossover cannot be fully evaluated without a stereoscopic view to provide depth perception.

2.7 AIME PRODUCTION CAPABILITY DEMONSTRATION

On 12 June 1980 a Production Capability Demonstration was conducted at RCA-Automated Systems. The twenty-three (23) invited representative from Government agencies/industry in attendance were briefed on the AIME program, system requirements, details : the system hardware/software and its operation, analysis of test results, and a demonstration of the AIME system capabilities. The overall technical accomplishments of the program was universally recognized and specific group interest surfaced regarding potential continuation of development/evaluation addressing visual inspection of multi-layer thick-film substrates and thin-film substrates.

The list of attendees is provided in Appendix C. In addition, the attendees were requested to respond to a survey questionaire profiling their micro-electronic production/inspection process. The results of this survey is provided in Appendix D.

SECTION 3
CONCLUSIONS

3.1 RESULTS OF DATA GATHERING

The results of data gathering and evaluation indicate that the AIME demonstration system can successfully detect substrate defects of varying sizes. Overall AIME detected 96.4 percent of all substrate defects. When the defects were classified by size, AIME detected 100 percent of defects three mils or larger and 81 percent of defects less than three mils. Table 3-1 gives a summary of the data taken during data gathering and evaluation. Appendix B contains the data sheets showing the type and quantity of defects found on each of the twelve substrates that were evaluated.

3.2 HIGH SPEED INSPECTION TECHNIQUES

As a result of the analysis performed to determine the high speed inspection capability of the AIME demonstration system, it can be concluded that inspection rates of up to 750 substrates per hour may be tested.

SUBSTRATE NUMBER	TOTAL NUMBER OF DEFECTS	TOTAL NUMBER 0-3 MIL DEFECTS	TOTAL NUMBER 3-6 MIL DEFECTS	TOTAL NUMBER >6 MIL DEFECTS	TOTAL DEFECTS DETECTED	0-3 MIL DEFECTS DETECTED	3-6 MIL DEFECTS DETECTED	>6 MIL DEFECTS DETECTED	DEFECTS MISSED
2A1	24	5	7	12	24	5	7	12	0
3A1	33	6	14	13	30	3	14	13	3
3A2	26	1	8	17	26	1	8	17	0
4A1	34	2	15	17	34	2	15	17	0
4A2	30	0	13	17	30	0	13	17	0
5A1	19	12	6	1	16	9	6	1	3
5A2	16	10	6	0	15	9	6	0	1
6A1	22	2	10	10	22	2	10	10	0
6A2	20	4	9	7	20	4	9	7	0
7A1	36	11	15	10	35	10	15	10	1
8A1	35	4	13	18	34	3	13	18	1
8A2	36	6	20	10	33	3	20	10	3
TOTAL	331	63	136	132	319	51	136	132	12

TABLE 3-1 SUMMARY OF AIME DATA

3.3 ADDITIONAL DEVELOPMENT REQUIREMENTS

3.3.1 Selection of Another Camera to Replace the RBV Camera

The RBV camera presently used on the AIME Demonstration System is over twelve years old and is no longer produced. Future development requires the selection of a suitable replacement to RBV camera. The camera chosen for AIME must be capable of high resolution over the entire substrate image area, and one providing a readout at a continuous rate with a steady-state optical exposure or in near-real time storage and readout with a discrete input consisting of a shutted exposure. It is also required that electronic zoom be employed without raster burn to preserve high resolution while retaining compatability with standard rate devices and displays.

In conjunction with alternate tube investigation, it is recommended that attention be given to the pre-cap inspection requirement. Alternate methods of zoom ratios, raster scan rates and special high-resolution displays should be considered to provide a high-resolution and more practical pre-cap inspection capability, including a steroscopic view capability for adequate depth perception. In addition further development may warrant separation of the system into 2 independent units, one with automatic line inspection capability and one for pre-cap inspection. This will simplify the design of each unit and make each one more economically attractive.

3.3.2 Correction of Time Base Corrector Unit Deficiencies

The time Base Corrector (TBC) unit in the AIME Demonstration System aligns the playback video form the video recorder with the camera video to within 10 nano-seconds. However, the TBC unit currently in use exhibits an inherent instability in the clock signal which is to provide horizontal lockup on each frame of the video signal. The instability is a cause for the identification of false defects during substrate testing. Correction of this problem requires either partial redesign of the TBC currently in use or in the selection of a new unit.

An investigation is also recommended to determine the feasibility and cost effectiveness of replacing the video recorder and TBC with alternate solid state storage devices.

3.3.3 Investigate and Modify AIME Hardware/Software to Accommodate Registration Variations Which Occurs During Substrate Printing

During the printing process, small variations occur in the line registration from substrate to substrate. These registration variations are inherent in the printing process and do not degrade the quality of the substrate when the substrates are detected on the AIME Demonstration System, the registration variations are detected and the substrate is erroneously declared defective. During the data gathering and evaluation task, registration variations were minimized through the manual realignment of the substrate. To enable AIME to test substrates at rates up to 750 substrates/hour, automatic realignment of the substrate is required. Investigation is required to determine the best method of correction either through hardware and/or software modification.

3.3.4 Multilayer Structures

The evaluation of substrate defects was confined to single layer films. Multilayer structures require further investigation to determine effects of layer interferences.

DISTRIBUTION LIST

15 September 1980

US ARMY ELECTRONICS TECHNOLOGY & DEVICES LABORATORY

MANDATORY CONTRACT DISTRIBUTION LIST

# OF COPIES	
012	Defense Technical Information Center ATTN: DTIC-TCA Cameron Station (Bldg 5) Alexandria, VA 22314
001	GIDEP Engineering & Support Dept TE Section PO Box 398 Norco, CA 91760
001	Director Naval Research Laboratory ATTN: Code 2627 Washington, DC 20375
001	Rome Air Development Center ATTN: Documents Library (TILD) Griffiss AFB, NY 13441
001	Deputy For Science & Technology Office, Asst Sec Army (R&D) Washington, DC 20310
001	HQDA (DAMA-ARZ-D/Dr. F.D. Verderame) Washington, DC 20310
001	Director US Army Materiel Systems Analysis Actv ATTN: DRXSY-T Aberdeen Proving Ground, MD 21005
001	Commander, DARCOM ATTN: DRCDE 5001 Eisenhower Avenue Alexandria, VA 22333
001	Cdr, US Army Signals Warfare Lab ATTN: DELSW-OS Vint Hill Farms Station Warrenton, VA 22186
001	Commander US Army Communications R&D Command ATTN: USMC-LNO Fort Monmouth, NJ 07703

# OF COPIES	
001	Cdr, PM Concept Analysis Centers ATTN: DRCPM-CAC Arlington Hall Station Arlington, VA 22212
001	Cdr, Night Vision & Electro-Optics ERADCOM ATTN: DELNV-D Fort Belvoir, VA 22060
001	Cdr, Atmospheric Sciences Lab ERADCOM ATTN: DELAS-SY-S White Sands Missile Range, NM 88002
001	Cdr, Harry Diamond Laboratories ATTN: DELHD-CO, TD (In Turn) 2800 Powder Mill Road Adelphi , MD 20783
001	Cdr, ERADCOM ATTN: DRDEL-CG, CD, CS (In Turn) 2800 Powder Mill Road Adelphi , MD 20783
001	Cdr, ERADCOM ATTN: DRDEL-CT 2800 Powder Mill Road Adelphi , MD 20783
000	Commander US Army Electronics R&D Command Fort Monmouth, NJ 07703
1	DELEW-D
1	DELET-D
1	DELSD-L (Tech Library)
2	DELSD-L-S (STINFO)
15	Originating Office DELET-IA-T
001	ITT ATTN: Steve Reiss 390 Washington Avenue Nutley, NJ 07110

15 September 1980

DISTRIBUTION LIST

# OF COPIES		# OF COPIES	
001	Rudy Thun, Mgr Raytheon Company Electronic Product Design Laboratory Hartwell Road Bedford, MA 01730	001	General Electric Co ATTN: Gary Flanagan French Road Plant Utica, New York 13503
001	Hybrid Systems Corp Crosby Drive ATTN: Ronald Visser Bedford, MA 01730	001	Rockwell International ATTN: Mr. Don Scott PO Box 1062 Dallas, TX 75207
001	Raytheon Company Equipment Division ATTN: Mr. Frank Cheriff 528 Boston Post Rd Sudbury, MA 01776	001	Brush Wellman ATTN: Michael Hutfless Elmore, Ohio 43416
001	Litton Guidance and Control Systems ATTN: Al Ertel 5500 Canoga Avenue Woodland Hills, CA 91364	001	Commander Harry Diamond Laboratory ATTN: Albert Lee 2800 Powder Mill Road Adelphi , MD 20783
001	Westinghouse Defense & Electronics Systems Center ATTN: Don Vincent PO Box 746 Baltimore, MD 21203	001	Hughes Aircraft Company Solid State Products Division ATTN: R. P. Himmel 500 Superior Avenue Newport Beach, CA 92663
002	Advisory Group on Electron Devices 201 Varich Street, 9th Floor New York, NY 10014	001	Manufacturing Technology Utilization NASA Headquarters ATTN: Ray L. Gilbert 608 Independence Ave., SW Washington, DC 20546
001	US Army Industrial Base Engrg Activity ATTN: DRXIB-MT (Mr. C. McBurney) Rock Island, IL 61299	001	Commander, DARCOM ATTN: DRCMT (Fred Michel) 5001 Eisenhower Avenue Alexandria, VA 22333
001	J. Degan Bell Laboratories 1600 Osgood Street North Andover, MA 01845		General Dynamics Electronics Division ATTN: Merrill Palmer PO Box 81127 San Diego , CA 92138
001	Commander Naval Ocean Systems Center ATTN: Dr. W. D. McKee, Jr. Code 9253T San Diego, CA 92152		Dr. Victor Ruwe Mgr, Microelectronics Functional Group US Missile Command ATTN: DRDMI-EAA Redstone Arsenal, AL 35803

15 September 1980

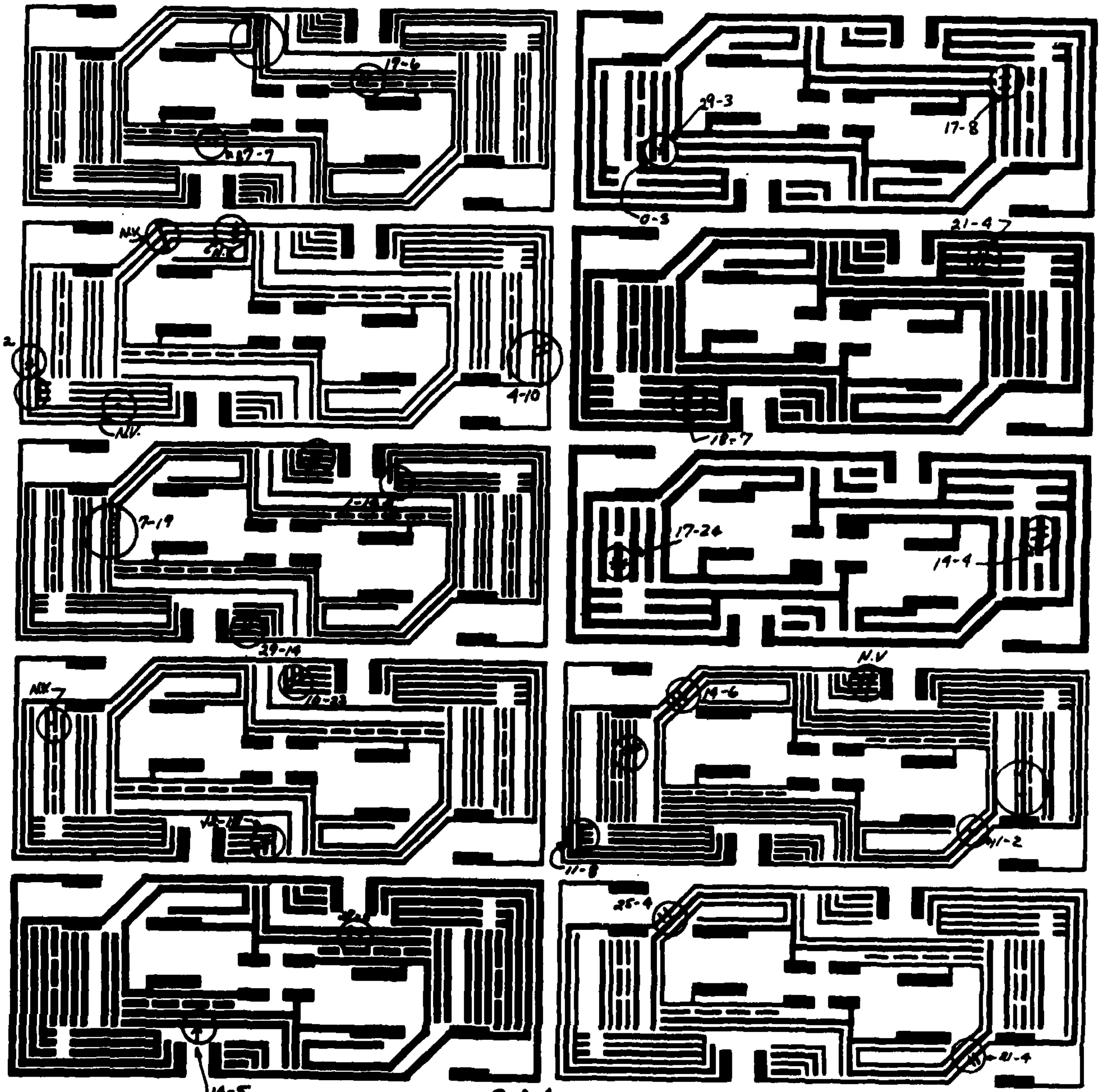
DISTRIBUTION LIST

# OF COPIES	
	Kulicke & Soffa Industries, Inc ATTN: Mr. M. Kulicke 507 Prudential Road
001	Hersham, PA 19044
	MIT-Lincoln Laboratory ATTN: Library (RM A-082) PO Box 73
001	Lexington, MA 02173
	Microwave Associates ATTN: Dr. F. Brand
001	Burlington, MA 01803
	A. J. Donnell DRDAR-LCA-PD USA ARDCOM
001	Dover, NJ 07801

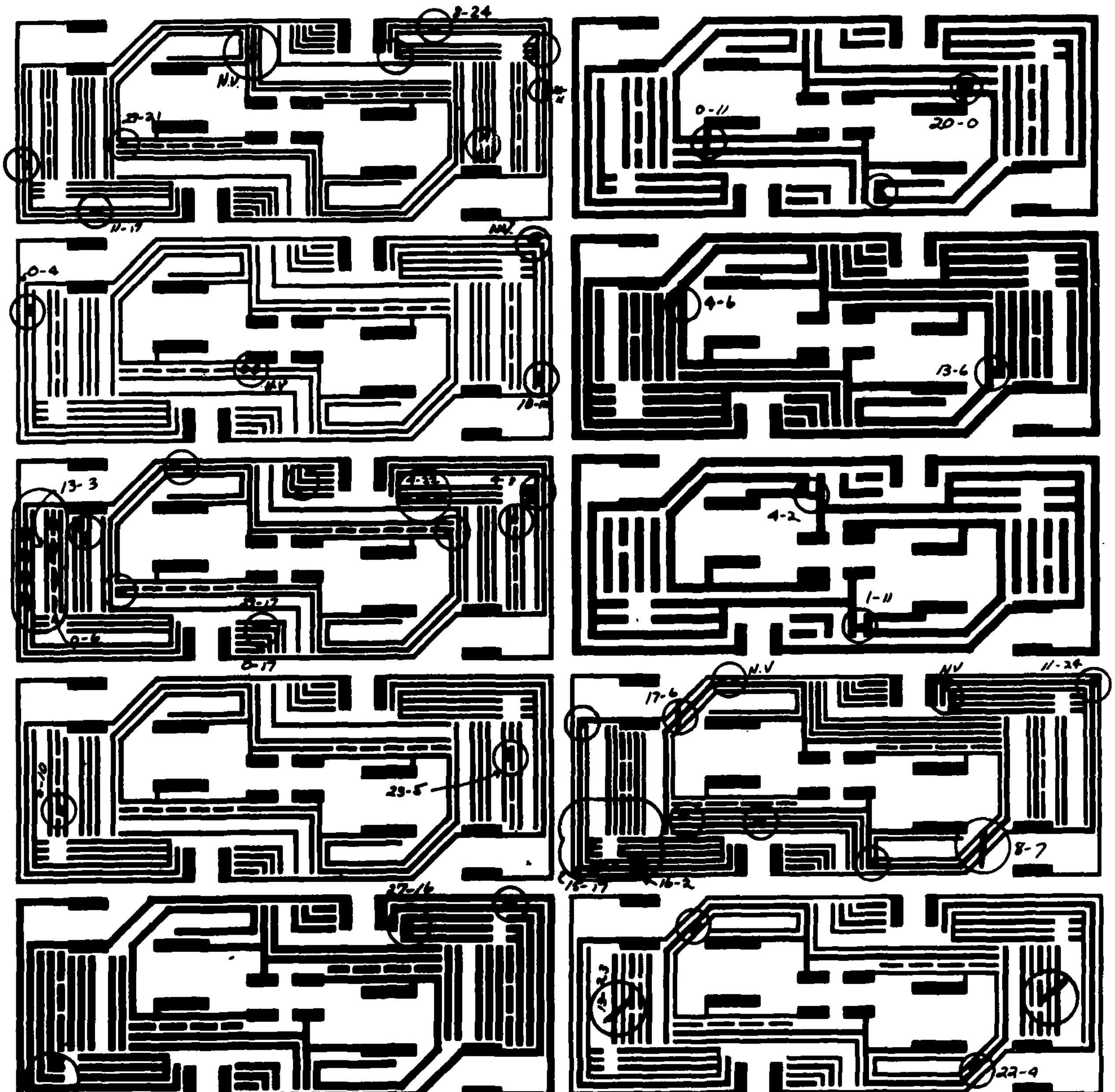
# OF COPIES	
	Jonathan Barrington Mgr, Market Development Electronic Materials Division E. I. Dupont de Nemours & Co Photo Products Division
001	Wilmington, DF 19898
	NASA Scientific & Tech Info Facility Baltimore/Washington Int'l Airport PO Box 8757
001	Maryland 21240
	Bell Laboratories Whippany Road ATTN: Tech Reports Center WH5E-227
001	Whippany, NJ 07981

APPENDIX A

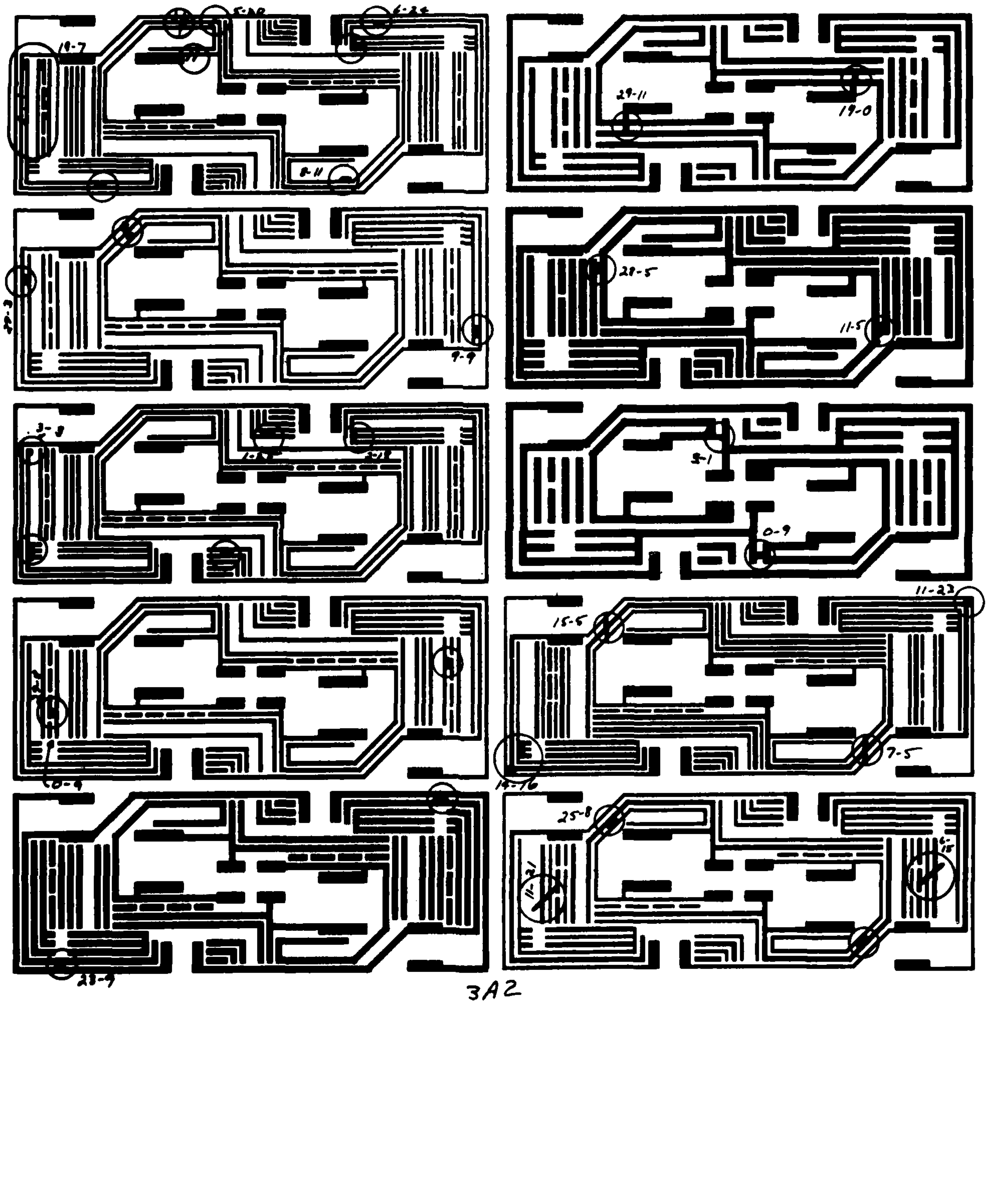
PICTORIAL VIEW OF EACH SUBSTRATE EVALUATED


19-6
17-7
29-3
17-8
0-3
N.V.
1-2
N.V.
4-10
21-4
18-7
7-19
17-24
14-4
29-14
N.V
14-6
11-2
11-8
25-4
21-4
14-5

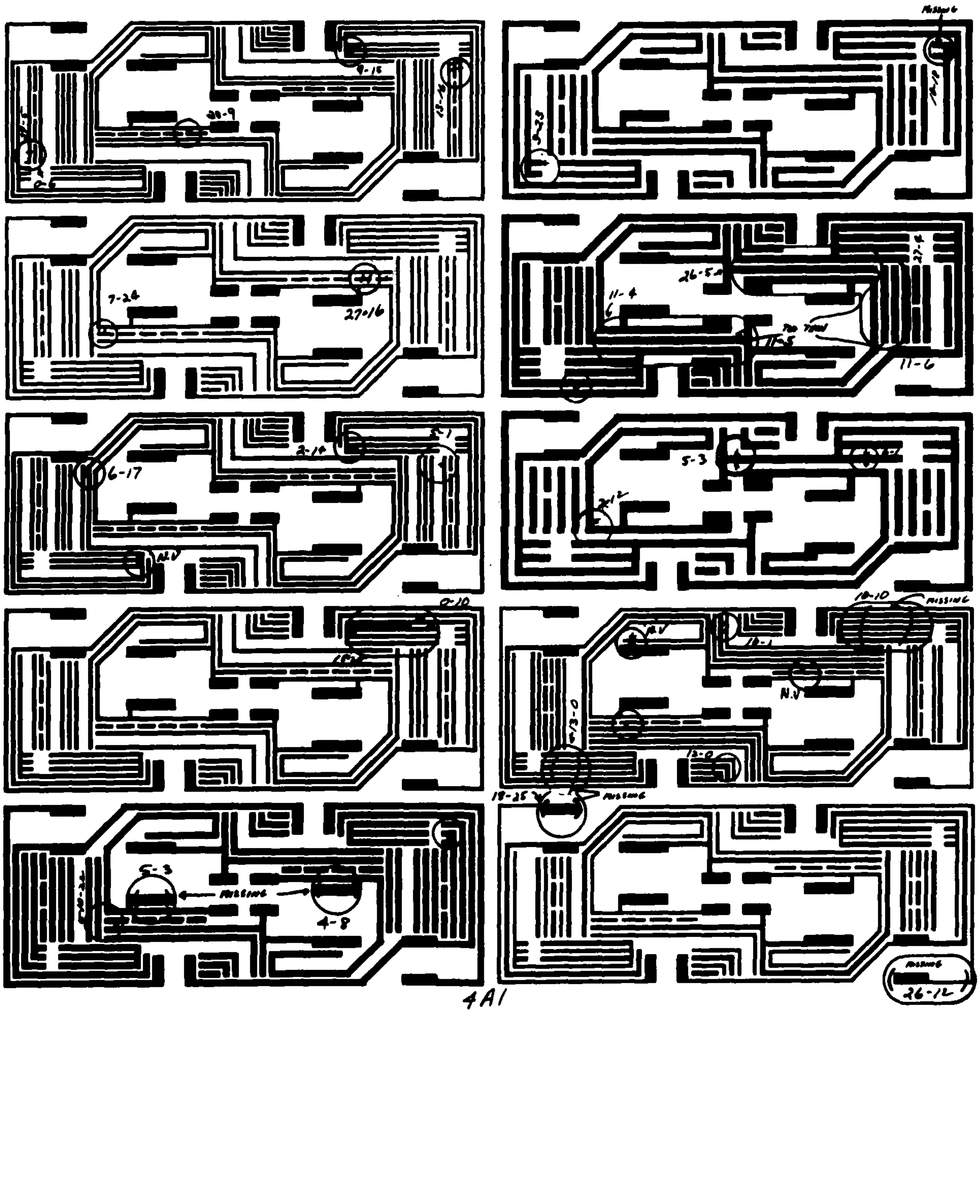
2A1


8-24
N.V.
23-21
N-17
0-11
20-0
0-4
4-6
13-6
13-3
0-6
0-17
4-2
1-11
23-5
17-6
N.V
NV
11-24
8-7
15-17
16-2
27-16
26-11
22-4

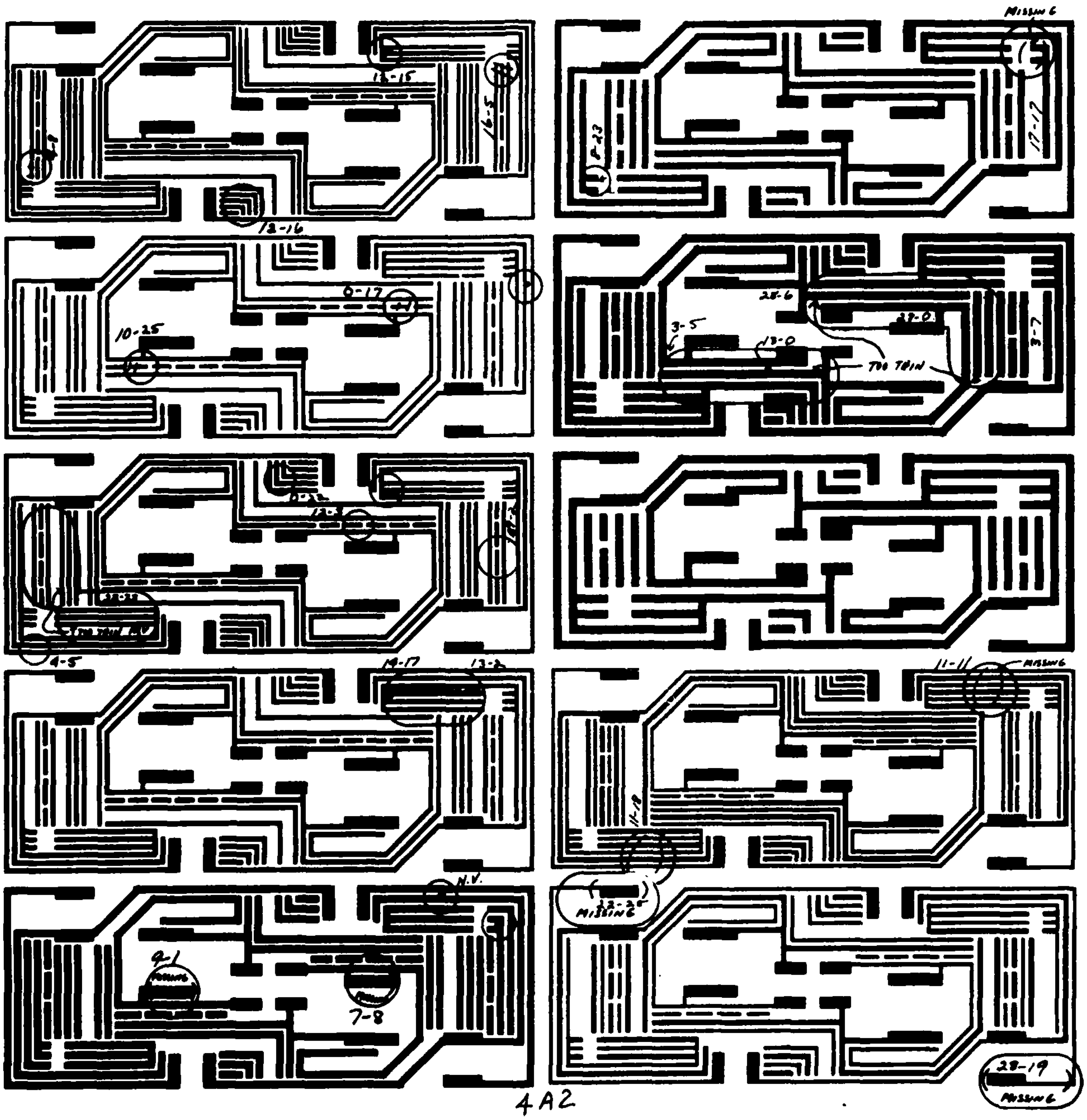
3A1



3A2

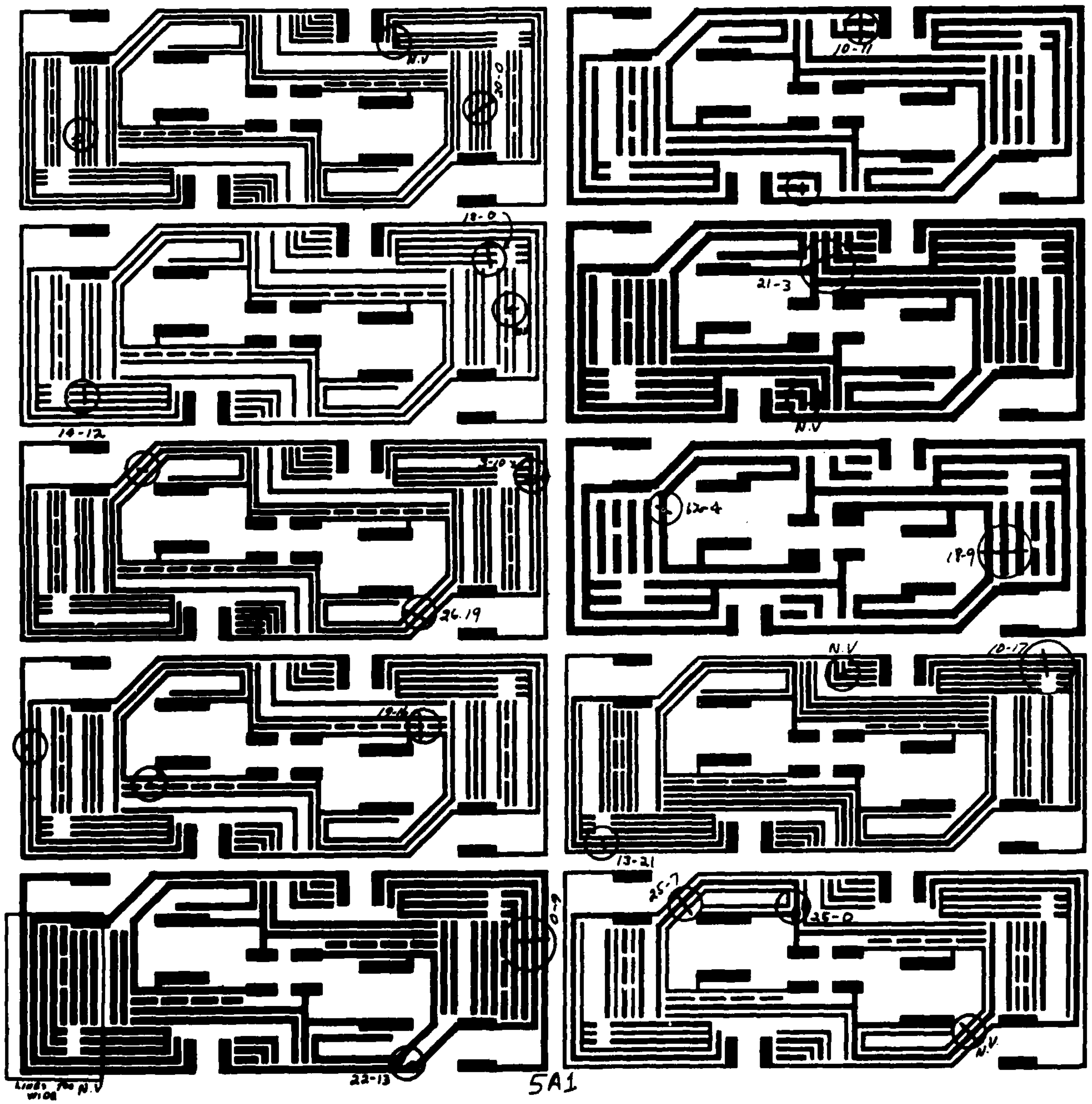


4A1

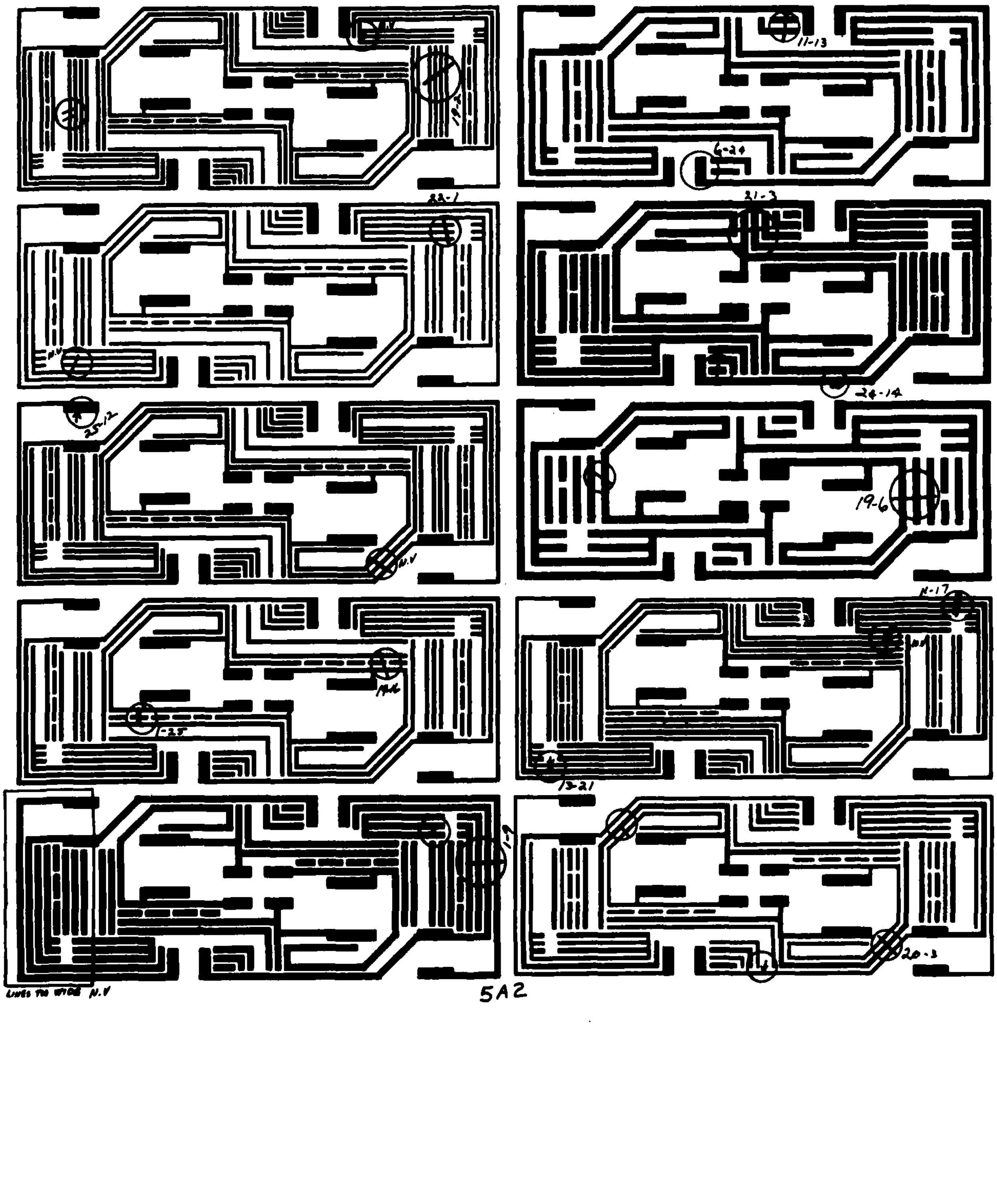


MISSING
12-16
10-25
TOO THIN
4-5
19-17
11-11
11-18
MISSING
7-8
N.V.
28-19
MISSING

4A2

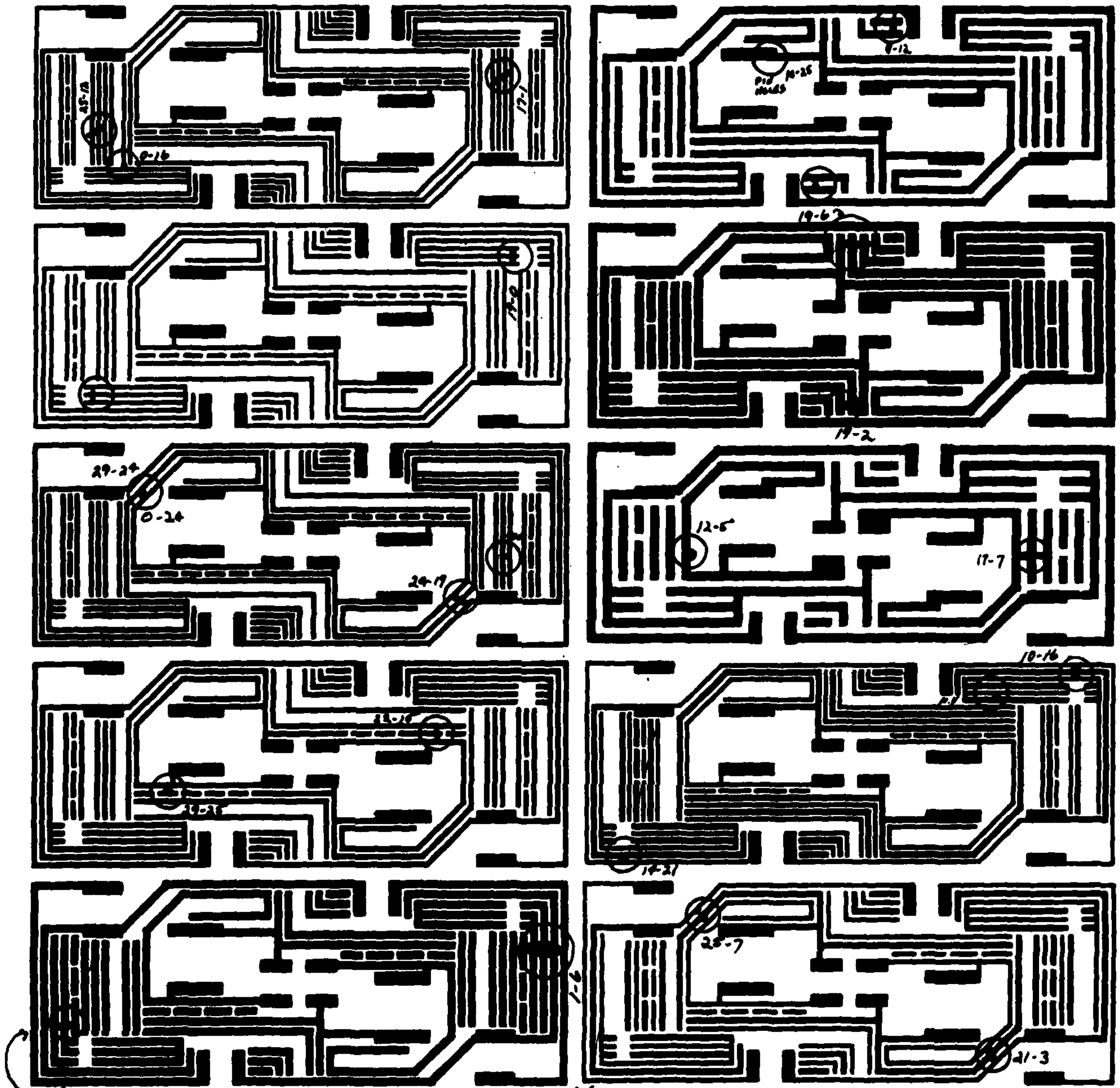

N.V
10-11
18-0
21-3
14-12
N.V
26.19
12-4
18-9
N.V
10-17
13-21
25-7
25-0
N.V
22-13
N.V

5A1

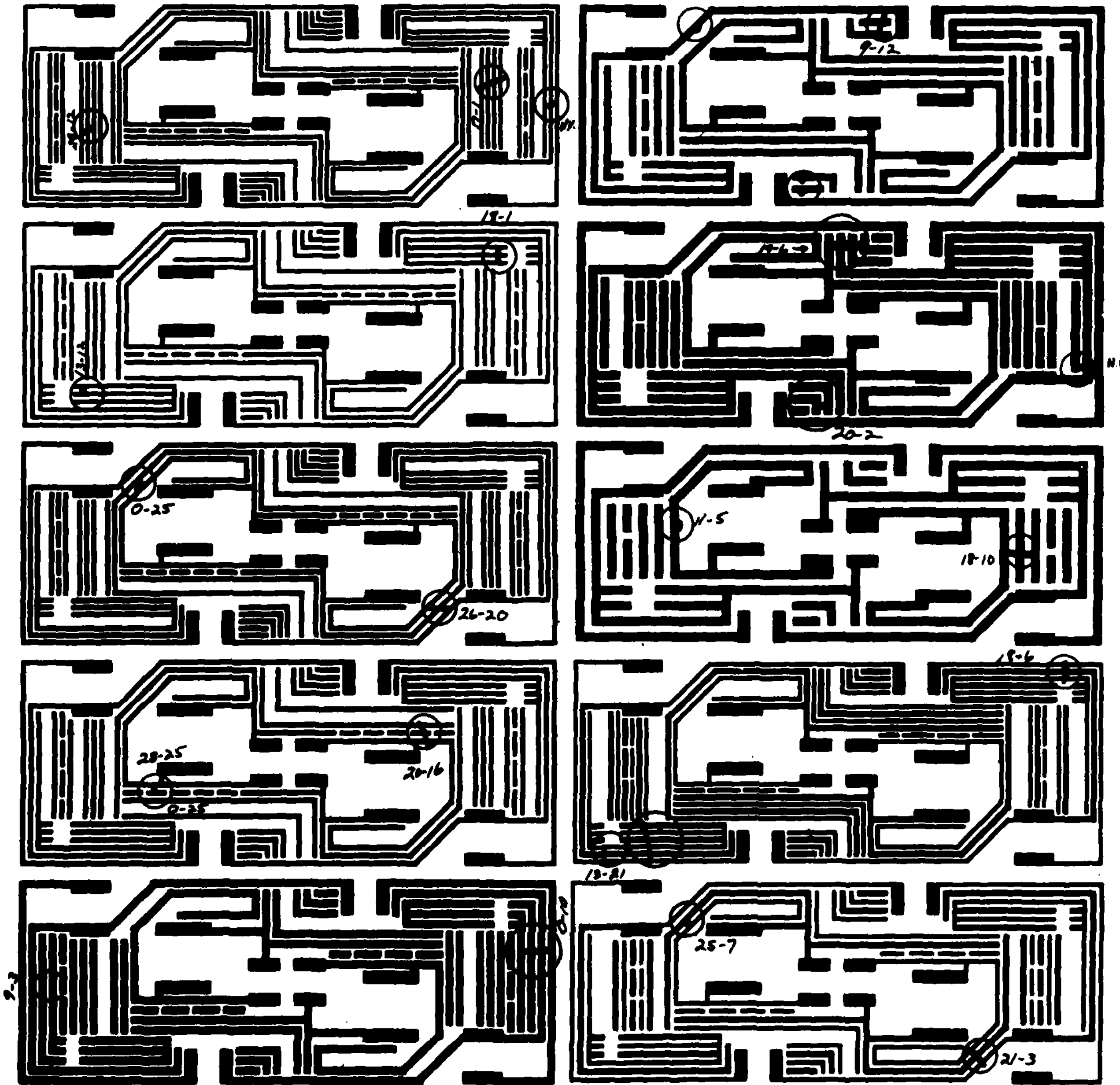


LINES TOO WIDE N.V

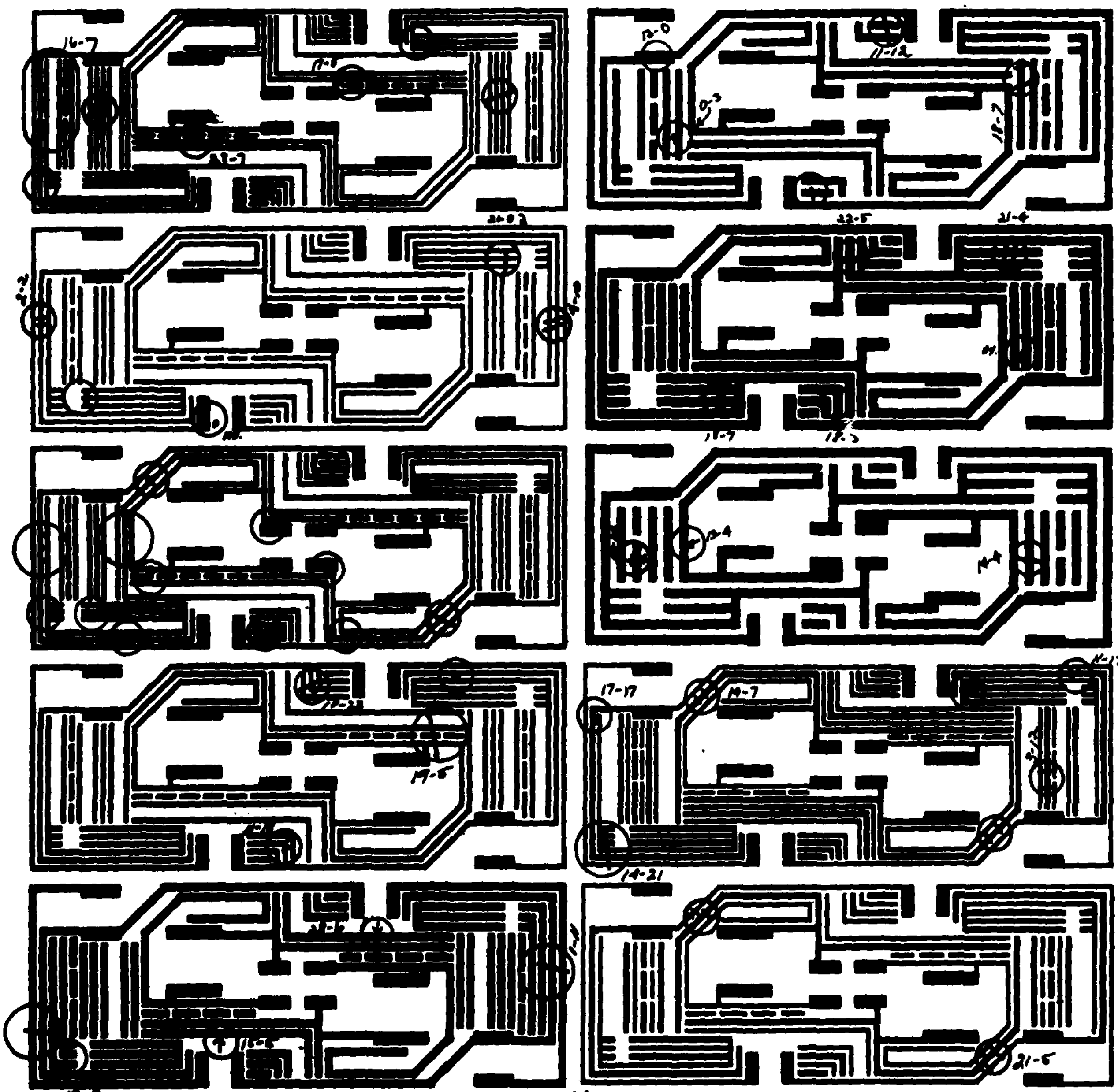
5A2



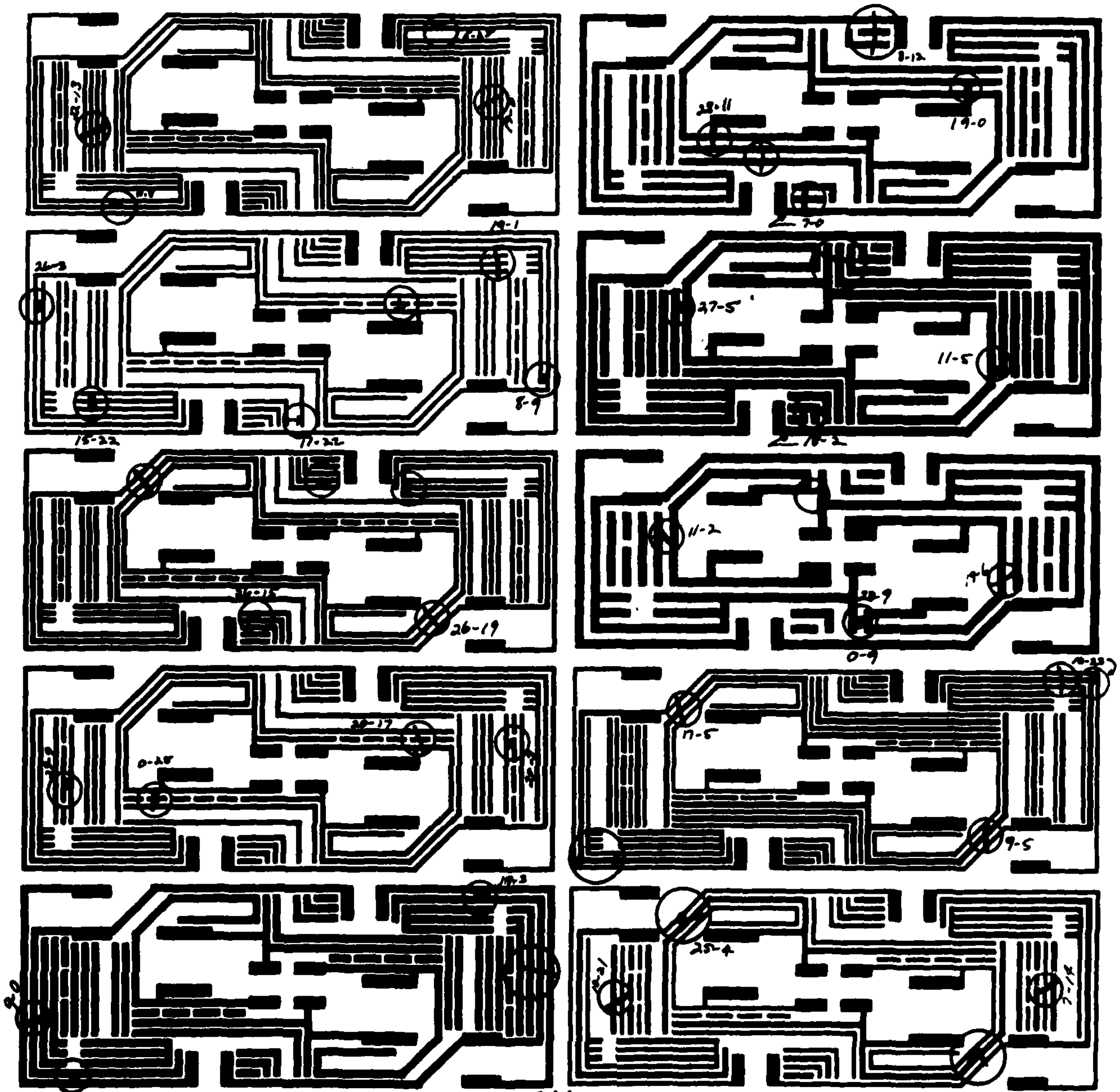
6A1



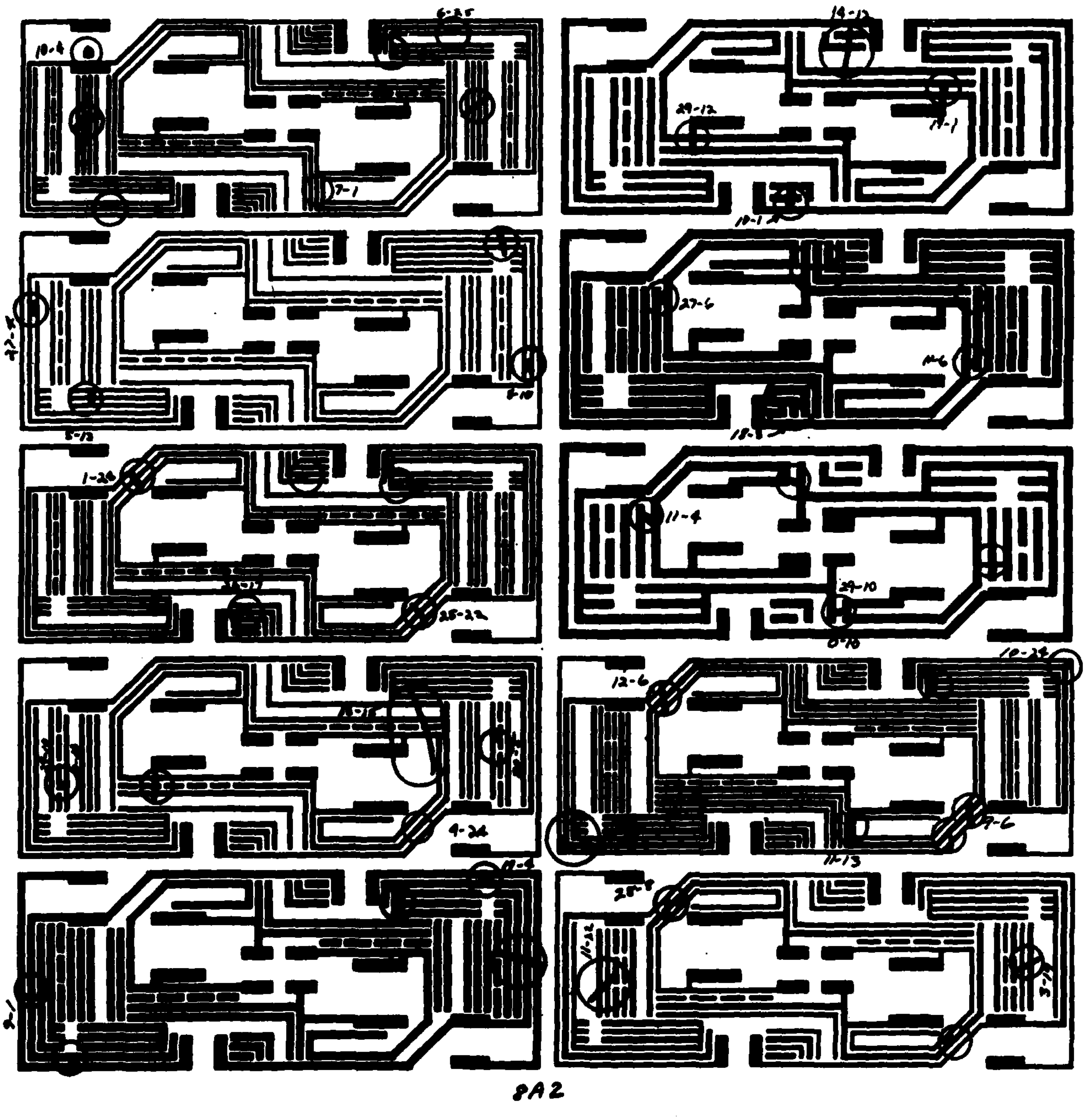
6A2



7A1



8A1



8A2

APPENDIX B
OPERATION RECORDED DATA

AIME

SUBSTRATE EVALUATION TEST DATA

SUBSTRATE TEST SAMPLE # 2A1

25 0	26 2M M 27-7	27 1L L 17-6	28 0	29 1L L 29-3	30 0	31 1L L 17-8
36 0	37 0	38 0	39 0	40 1M M 0-3	41 0	42 1L L 21-4
47 2S S 1-2	48 0	49 0	50 1M M 4-10	51 1L L 18-7	52 0	53 0
58 1S S 7-19	59 1M M 29-14	60 1S S 1-14	61 1L L 17-24	62 0	63 0	64 1L L 14-14
69 0	70 2M, 1L L 10-23	71 0	72 0	73 1M M 14-6	74 0	75 1L L 14-0
80 0	81 1M M 12-18	82 1L L 27-5	83 1S S 11-18	84 1S S 25-4	85 0	86 2L L 11-2
91 0	92 1L L 14-5	93 0	94 0	95 0	96 0	97 1M M 21-4

KEY:

SECTION NO. → 25
TOTAL DEFECTS* → 3L,1S
DEFECT FOUND* → L
DEFECT LOCATION ROW-COLUMN → 14-2

* DEFECT SIZES CODED AS FOLLOWS

S = 0-3 MILS
M = 3-6 MILS
L = >6 MILS

AIME

SUBSTRATE EVALUATION TEST DATA

SUBSTRATE TEST SAMPLE # 3A1

25 1S S 29-21	26 0	27 3M M 8-24	28 2M M 24-11	29 0	30 0	31 1L L 20-0
36 1S, 1M M 11-17	37 0	38 0	39 1S 0 -	40 1M M 0-11	41 1S 0 -	42 0
47 1L L 0-4	48 1S S 28-4	49 0	50 1L L 10-10	51 1M M 0-6	52 0	53 1L L 13-6
58 1M, 2L L 13-3	59 2M M 29-17	60 2M, L L 4-22	61 2M M 4-8	62 0	63 1L L 4-2	64 0
69 1M M 0-6	70 1M M 0-17	71 0	72 1M, 1L L 23-5	73 1L L 17-6	74 1L L 1-11	75 1M M 11-24
80 1M M 3-10	81 0	82 1M M 27-16	83 3M M 15-17	84 3M M 16-2	85 1S 0 -	86 1L L 8-7
91 1S S 26-11	92 0	93 0	94 1L L 13-23	95 0	96 0	97 2L L 22-4

KEY:

SECTOR NO. → 25
TOTAL DEFECTS* → 3L,1S
DEFECT FOUND* → L
DEFECT LOCATION ROW-COLUMN → 14-2

* DEFECT SIZES CODED AS FOLLOWS

S = 0-3 MILS
M = 3-6 MILS
L = >6 MILS

AIME

SUBSTRATE EVALUATION TEST DATA

SUBSTRATE TEST SAMPLE # 3A2

25 3M M 19-7	26 4M M 5-20	27 1L L 6-24	28 0	29 1L L 29-11	30 0	31 1L L 19-0
36 1S, 2M M 27-3	37 0	38 1M M 8-11	39 0	40 1L L 28-5	41 0	42 0
47 0	48 0	49 0	50 1L L 9-9	51 0	52 0	53 1L L 11-5
58 2S S 3-3	59 2L L 1-25	60 1M M 2-18	61 0	62 0	63 2M M 3-1	64 0
69 1M M 29-8	70 0	71 0	72 1L L 21-3	73 1L L 15-5	74 1L L 0-9	75 1L L 11-23
80 1L L 0-9	81 0	82 0	83 2L L 14-16	84 1L L 25-8	85 0	86 1L L 7-5
91 1M M 23-9	92 0	93 0	94 1L L 11-21	95 0	96 0	97 2L L 6-15

KEY:

SECTOR NO. → 25
TOTAL DEFECTS* → 3L,1S
DEFECT FOUND* → L
DEFECT LOCATION ROW-COLUMN → 14-2

* DEFECT SIZES CODED AS FOLLOWS

S = 0-3 MILS
M = 3-6 MILS
L = >6 MILS

AIME

SUBSTRATE EVALUATION TEST DATA

SUBSTRATE TEST SAMPLE # 4A1

25 1M M 29-5	26 1S S 28-9	27 1M M 9-15	28 1L L 13-6	29 0	30 0	31 1L L 10-18
36 1L L 0-6	37 0	38 1M M 27-16	39 1L L 3-23	40 1M M 26-4	41 1M M 26-5	42 1M M 27-4
47 1M M 7-24	48 0	49 0	50 0	51 2L L 11-4	52 1M M 11-5	53 1L L 11-6
58 1L L 6-17	59 0	60 2M M 2-14	61 2M M 5-1	62 2L L 21-2	63 2M M 5-3	64 2L L 6-1
69 1M M 23-13	70 0	71 2L L 15-25	72 1L L 10-0	73 0	74 1M M 10-1	75 1L L 10-10
80 1M M 0-13	81 0	82 1M M 2-25	83 1L L 18-25	84 2L L 13-0	85 1S S 12-0	86 0
91 1S S 10-22	92 1L L 5-3	93 1L L 4-8	94 0	95 0	96 0	97 1L L 26-12

KEY:
SECTOR NO. → 25
TOTAL DEFECTS* → 3L, 1S
DEFECT FOUND* → L
DEFECT LOCATION ROW-COLUMN → 14-2

* DEFECT SIZES CODED AS FOLLOWS

S = 0-3 MILS
M = 3-6 MILS
L = >6 MILS

AIME

SUBSTRATE EVALUATION TEST DATA

SUBSTRATE TEST SAMPLE # 4A2

25 0	26 0	27 1M M 12-15	28 1L L 16-5	29 0	30 0	31 1L L 14-17
36 1L L 4-8	37 1M M 12-16	38 0	39 1M M 8-23	40 0	41 1M M 28-6	42 1M M 28-0
47 1M M 10-25	48 0	49 1M M 0-17	50 0	51 1M M 3-5	52 1M M 13-0	53 1M M 3-7
58 2L L 22-23	59 1L L 0-22	60 3L L 12-13	61 2L L 9-2	62 1L L 25-18	63 1L L 9-3	64 1L L 9-10
69 1M M 4-5	70 0	71 1L L 14-17	72 1M M 13-2	73 0	74 0	75 1L L 11-11
80 0	81 0	82 0	83 1S, 1L L 22-25	84 2L L 11-8	85 0	86 0
91 0	92 1L L 9-1	93 1L L 7-8	94 0	95 0	96 1M M 25-15	97 1L L 28-19

KEY:

SECTOR NO. → 25

TOTAL DEFECTS* → 3L,1S

DEFECT FOUND* → L

DEFECT LOCATION ROW-COLUMN → 14-2

* DEFECT SIZES CODED AS FOLLOWS

S = 0-3 MILS
M = 3-6 MILS
L = >6 MILS

AIME

SUBSTRATE EVALUATION TEST DATA

SUBSTRATE TEST SAMPLE # 5A1

25 1S 0 -	26 0	27 0	28 1S S 20-0	29 0	30 1S S 10-11	31 0
36 0	37 0	38 0	39 1M M 18-0	40 0	41 2S S 21-3	42 0
47 1S S 14-12	48 0	49 0	50 0	51 0	52 0	53 0
58 1S 0 -	59 0	60 1S S 26-19	61 1S S 3-10	62 1S S 12-4	63 0	64 1M M 18-9
69 2S 0 -	70 0	71 1M M 19-16	72 0	73 0	74 0	75 1M M 10-17
80 0	81 0	82 0	83 1S S 13-21	84 2S S 25-7	85 1M M 25-0	86 0
91 0	92 0	93 1M M 22-13	94 1L L 0-9	95 0	96 0	97 0

KEY:

SECTOR NO. → 25
TOTAL DEFECTS* → 3L, 1S
DEFECT FOUND* → L
DEFECT LOCATION ROW-COLUMN → 14-2

* DEFECT SIZES CODED AS FOLLOWS

S = 0-3 MILS
M = 3-6 MILS
L = >6 MILS

AIME

SUBSTRATE EVALUATION TEST DATA

SUBSTRATE TEST SAMPLE # 5A2

25 1S 0 -	26 0	27 0	28 1S S 19-2	29 0	30 1M M 11-13	31 0
36 0	37 0	38 0	39 1M M 22-1	40 1M M 6-24	41 2S S 21-3	42 0
47 1S S 25-12	48 0	49 0	50 0	51 0	52 2S S 24-14	53 0
58 0	59 0	60 0	61 0	62 1S S 12-4	63 0	64 1M M 19-6
69 0	70 0	71 1M M 19-16	72 0	73 0	74 0	75 1M M 11-17
80 1S S 1-25	81 0	82 0	83 1S S 13-21	84 0	85 0	86 0
91 0	92 0	93 0	94 1S S 1-9	95 0	96 0	97 1S S 20-3

KEY:

SECTOR NO. → 25

TOTAL DEFECTS* → 3L,1S

DEFECT FOUND* → L

DEFECT LOCATION ROW-COLUMN → 14-2

* DEFECT SIZES CODED AS FOLLOWS

S = 0-3 MILS

M = 3-6 MILS

L = >6 MILS

AIML

SUBSTRATE EVALUATION TEST DATA

SUBSTRATE TEST SAMPLE # 6A1

25 1M M 25-12	26 0	27 0	28 1L L 17-1	29 1L L 14-25	30 1L L 9-12	31 0
36 1S S 0-16	37 0	38 0	39 1M M 19-0	40 0	41 1M, 1L L 19-6	42 0
47 2M M 29-24	48 0	49 0	50 0	51 0	52 1M M 19-2	53
58 1M M 0-24	59 0	60 1L L 24-19	61 0	62 1M M 12-5	63 0	64 1L L 17-17
69 1M M 29-25	70 1S S 5-4	71 1L L 22-15	72 0	73 0	74 0	75 1L L 10-16
80 0	81 0	82 0	83 1M M 14-21	84 1M M 25-7	85 0	86 0
91 1M M 10-5	92 0	93 0	94 1L L 1-6	95 0	96 0	97 1L L 21-3

KEY:
SECTOR NO.
TOTAL DEFECTS*
DEFECT FOUND*
DEFECT LOCATION
ROW-COLUMN

25 3L,1S L 14-2

* DEFECT SIZES CODED AS FOLLOWS

S = 0-3 MILS
M = 3-6 MILS
L = >6 MILS

AIME

SUBSTRATE EVALUATION TEST DATA

SUBSTRATE TEST SAMPLE # 6A2

25 1L L 24-12	26 0	27 0	28 1L L 17-1	29 0	30 1L L 9-12	31 0
36 0	37 0	38 0	39 1M M 18-1	40 0	41 1S, 1L L 19-6	42 0
47 1M M 13-12	48 0	49 0	50 0	51 0	52 1M M 20-2	53 0
58 1M M 0-25	59 0	60 1L L 26-20	61 0	62 1M M 11-5	63 0	64 1L L 18-10
69 1S S 28-25	70 0	71 1L L 20-16	72 0	73 0	74 0	75 1M M 18-6
80 1S S 0-25	81 0	82 0	83 1S S 13-21	84 2M M 25-7	85 0	86 0
91 1S S 9-3	92 0	93 0	94 1M M 0-10	95 0	96 0	97 1M M 21-3

KEY:

SECTOR NO. → 25

TOTAL DEFECTS* → 3L, 1S

DEFECT FOUND* → L

DEFECT LOCATION ROW-COLUMN → 14-2

* DEFECT SIZES CODED AS FOLLOWS

S = 0-3 MILS

M = 3-6 MILS

L = >6 MILS

AIME

SUBSTRATE EVALUATION TEST DATA

SUBSTRATE TEST SAMPLE # 7A1

25 1S, 1L L 16-7	26 1M M 28-7	27 1S, 1M M 17-5	28 1S 0 -	29 2M M 13-0	30 1S S 11-12	31 1L L 18-7
36 2S S 0-3	37 0	38 0	39 1S S 21-0	40 1M M 0-3	41 1S, 1M M 22-5	42 1L L 21-4
47 2S S 2-2	48 0	49 0	50 1M M 4-10	51 1L L 18-7	52 1S S 18-3	53 0
58 4S S 26-11	59 0	60 1S S 2-14	61 1M M 18-24	62 1M M 13-4	63 0	64 1S, 1L L 14-14
69 1S S 0-12	70 1M, 1L L 10-23	71 2M M 19-15	72 1M M 17-17	73 1M M 14-7	74 0	75 2M M 11-17
80 0	81 1M M 11-18	82 1L L 28-6	83 1M M 14-21	84 2M M 1-13	85 0	86 2L L 3-12
91 2S S 17-7	92 1L L 15-5	93 0	94 1S S 1-11	95 0	96 0	97 1L L 21-5

KEY:

SECTOR NO. → 25
TOTAL DEFECTS* → 3L, 1S
DEFECT FOUND* → L
DEFECT LOCATION ROW-COLUMN → 14-2

* DEFECT SIZES CODED AS FOLLOWS

S = 0-3 MILS
M = 3-6 MILS
L = >6 MILS

AIME

SUBSTRATE EVALUATION TEST DATA

SUBSTRATE TEST SAMPLE # 8A1

25 1M M 22-13	26 0	27 1M M 5-25	28 1M M 19-0	29 1L L 28-11	30 1M M 8-12	31 1L L 19-0
36 1M M 26-3	37 0	38 1S 0 -	39 1S S 19-1	40 1M M 27-5	41 1M, 1L L 7-0	42 0
47 1L L 15-12	48 1S S 17-22	49 0	50 1L L 8-9	51 0	52 2M M 18-2	53 1L L 11-5
58 1M M 0-22	59 2L L 26-15	60 1S S 26-19	61 0	62 1M M 11-2	63 2L L 28-9	64 1M M 19-6
69 1M M 29-9	70 0	71 1M M 20-17	72 1L L 20-3	73 1L L 17-5	74 1L L 0-9	75 1S, 1L L 10-23
80 1M M 0-25	81 0	82 0	83 3L L 19-3	84 1L L 25-4	85 0	86 1L L 9-5
91 1S, 1L L 9-0	92 0	93 0	94 1S, 1L L 10-21	95 0	96 0	97 2L L 7-14

Y:

SECTOR NO. → 25
TOTAL DEFECTS* → 3L, 1S
DEFECT FOUND* → L
DEFECT LOCATION ROW-COLUMN → 14-2

* DEFECT SIZES CODED AS FOLLOWS

S = 0-3 MILS
M = 3-6 MILS
L = >6 MILS

AIME

SUBSTRATE EVALUATION TEST DATA

SUBSTRATE TEST SAMPLE # 8A2

25 2L L 10-4	26 0	27 1M M 6-25	28 1S 0 -	29 1M M 29-12	30 1S S 14-12	31 1L L 19-1
36 2M M 27-4	37 0	38 1S S 7-1	39 1S 0 -	40 1M M 27-6	41 1L, 1M L 10-1	42 0
47 1L L 15-13	48 0	49 0	50 1L L 8-10	51 0	52 1M M 18-3	53 1M M 11-6
58 1M M 1-24	59 2M M 26-17	60 2M M 25-22	61 0	62 1M M 11-4	63 1M, 1L L 29-10	64 1S 0 -
69 1M M 29-10	70 0	71 1M M 13-15	72 1M M 20-5	73 1M M 12-6	74 1M M 0-10	75 1S, 1M M 10-24
80 1M M 0-10	81 0	82 2S S 4-24	83 2M M 19-4	84 1L L 28-8	85 1L L 11-13	86 1S, 1M M 9-6
91 1S, 1M M 9-1	92 0	93 0	94 1S, 1L L 11-22	95 0	96 0	97 1M, 1L L 3-19

KEY:

SECTOR NO. → 25
TOTAL DEFECTS* → 3L,1S
DEFECT FOUND* → L
DEFECT LOCATION ROW-COLUMN → 14-2

* DEFECT SIZES CODED AS FOLLOWS

S = 0-3 MILS
M = 3-6 MILS
L = >6 MILS

APPENDIX C

AIME PRODUCTION CAPABILITY DEMONSTRATION

ATTENDANCE LIST

AIME CAPABILITY DEMONSTRATION
12 JUNE 1980
ATTENDEES

STEVE REISS
ITT AVIONICS
NUTLEY, NJ

JAMES R. DINITTO
RAYTHEON
BEDFORD, MA

DR. RUDOLF E. THUN
RAYTHEON
BEDFORD, MA

ROBERT REGO
RAYTHEON
BEDFORD, MA

TOM WEIN
RAYTHEON
BEDFORD, MA

TED COCCA
RAYTHEON
BEDFORD, MA

AL ERTEL
LITTON
WOODLAND HILLS, CA

DON SCOTT
ROCKWELL INTERNATIONAL
DALLAS, TX

RONALD VISSER
HYBRID SYSTEMS INC.
BEDFORD, MA

HANK DIPIETRO
HYBRID SYSTEMS INC.
BEDFORD, MA

GARY FLANAGAN
GENERAL ELECTRIC
UTICA, NY

RON FESS
GENERAL ELECTRIC
UTICA, NY

CARL LONGLEY
GENERAL ELECTRIC
UTICA, NY

RICHARD FOERSTER
GENERAL ELECTRIC
PLAINVILLE, CT

FRANK CHERIFF
RAYTHEON
SUDBURY, MA

RAYMOND LABRIE
RAYTHEON
SUDBURY, MA

JOSEPH KEY
US ARMY ELECT. TECH. & DEVICES LAB.
FT. MONMOUTH, NJ

I. H. PRATT
USA ELECTRONICS R&D COMMAND
FT. MONMOUTH, NJ

MICHAEL HUTFLESS
BRUSH WELLMAN
ELMORE, OH

DON VINCENT
WESTINGHOUSE
BALTIMORE, MD

ALBERT LEE
HARRY DIAMOND LABS
ADELPHI, MD

OWEN P. LAYDEN
USA ERADCOM
FT. MONMOUTH, NJ

RAY SIMIONE
MICROWAVE ASSOCIATES
BURLINGTON, MA

ROGER STURTEVANT
MICROWAVE ASSOCIATES
BURLINGTON, MA

APPENDIX D

AUTOMATIC VISUAL INSPECTION SYSTEM

MARKET SURVEY QUESTIONNAIRE RESPONSE

AUTOMATIC VISUAL INSPECTION SYSTEM
MARKET SURVEY QUESTIONAIRE
SUMMARY

(1) Potential Application

Type	Quantity Produced/Year
Thick Film Hybrid	<10K - 14%; 10K/100K - 57%; 100K/1M - 29%
Thin Film Hybrid	20K/100K - 42%
Monolithic	<100K - 14%

(2a) Identify the Characteristics of Your Application

	Thick Film Hybrid	Thin Film Hybrid	Monolithic
High Volume, Few Types	37%		
High Volume, Many Types		25%	50%
Low Volume, Large No.of Types	63%	75%	50%
Other (Please Explain)			

(2b) Please Characterize Your Typical Thick Film Network Printing Production Run (Quality Printed/Printing Rate)

Mil/Hi-Rel: 100-200/hr./print; 500-1K/lot; 5-10K/month

Commercial: 350/hr/print; 5K/lot; 20K/month

(3) Size of Substrates (Minimum and Maximum in Mils)

Minimum	500	x	1000
Maximum	5000	x	5000

(4a) What Are The Number of Circuit Types/Week Do You Visually Inspect?

<10 - 29%; 10/20 - 57%; >20 - 14%

Automatic Visual Inspection System
Market Survey Questionaire (Cont.)

(4b) What is Your Current Visual Inspection Rate? (Circuits/Hour/Operator)

1/10 - 60%; 50/60 - 40%

(5a) What Percentage of Circuits Produced are Visually Inspected?

Mil/Hi-Rel: 100%

Commercial: 10-50%

(5b) What are Present Levels of Visual Inspection for Each Circuit Type?

Varied

(5c) What Level of Visual Inspection Would You Desire if a System Were Available and Cost Effective?

100%

(5d) If an Automatic/Semi-Automatic Visual Inspection System were Available, What Inspection Rate Would You Desire?

20-30/hour	29%
500/hour	42%
>500/hour	29%

(6) What is Your Present Visual Inspection Cost (Approximate) Per Circuit?

Range $0.05 to $225/circuit

57% did not know

(7) What Percentage of Circuit Production Cost does Visual Inspection Represent?

Range 5% - 15%

(8) Characterize Your Visual Inspection Requirements. List Type of Defects.

Circuit breaks/voids in resistors

Registration/smears/splatters

Shorts between conductors/resistors

Via coverage/alignment

Dielectric coverage/alignment

Contamination/staining

Blisters/flaking

Resister trin

Assembly - device type/orientation/wiring/bonding

(9) Do You Inspect to Criteria Specified in MIL-STD-883? 70%

(a) Method 2010 - Precap Visual for Monolithics ________

(b) Method 2017 - Precap Visual for Hybrids ________

(c) Both of the Above Separately ________

(d) Both 2010 and 2017 at The Same Inspection Point ________

(10) What Amortization Period would be Specified for Investments in Inspection Station Equipment?

For Mil/Hi Rel requirements: range 2-10 years

average 5 years

(11) List Below the Other Requirements You Have That are Not Covered in (1) through (9).

The survey response provided a profile of typical hybrid manufacturers with a current production range of 10K to 1M circuits/year. Significant increases in volume are anticipated within the next five years as hybrid devices find wider application, particularly in the commercial area. The data tends to support the conclusion that current in-process visual inspection is time (and cost) constrained. A need exists for more automated methods of in-process inspection to improve yield and assure a higher degree of quality control.

AUTOMATIC VISUAL INSPECTION SYSTEM
MARKET SURVEY QUESTIONAIRE

(1) Potential Application

Type	Quantity Produced/Year
Thick Film Hybrid	✓ over 10,000 hybrids
Thin Film Hybrid	✓
Monolithic	✓ over 100,000 monolithics

(2a) Identify the Characteristics of Your Application

	Thick Film Hybrid	Thin Film Hybrid	Monolithic
High Volume, Few Types			
High Volume, Many Types			
Low Volume, Large No.of Types	✓		✓
Other (Please Explain)		few types	

(2b) Please Characterize Your Typical Thick Film Network Printing Production Run (Quality Printed/Printing Rate)

10 mil on 20 mil centers

Some 4 mil lines

(3) Size of Substrates (Minimum and Maximum in Mils)

Minimum 1' x 1'

Maximum 5' x 5'

(4a) What Are The Number of Circuit Types/Week Do You Visually Inspect?

20

Automatic Visual Inspection System
Market Survey Questionaire (Cont.)

(4b) What is Your Current Visual Inspection Rate? (Circuits/Hour/Operator)

2

(5a) What Percentage of Circuits Produced are Visually Inspected?

100%

(5b) What are Present Levels of Visual Inspection for Each Circuit Type?

38510 Class B

(5c) What Level of Visual Inspection Would You Desire if a System Were Available and Cost Effective?

Same

(5d) If an Automatic/Semi-Automatic Visual Inspection System were Available, What Inspection Rate Would You Desire?

20 per hour

(6) What is Your Present Visual Inspection Cost (Approximate) Per Circuit?

-

(7) What Percentage of Circuit Production Cost does Visual Inspection Represent?

-

(8) Characterize Your Visual Inspection Requirements. List Type of Defects.

Full Mil Std.

(9) Do You Inspect to Criteria Specified in MIL-STD-883?

(a) Method 2010 - Precap Visual for Monolithics — Yes

(b) Method 2017 - Precap Visual for Hybrids — Yes

(c) Both of the Above Separately — -

(d) Both 2010 and 2017 at The Same Inspection Point — Yes

(10) What Amortization Period would be Specified for Investments in Inspection Station Equipment?

7 Years

(11) List Below the Other Requirements You Have That are Not Covered in (1) through (9).

AUTOMATIC VISUAL INSPECTION SYSTEM

MARKET SURVEY QUESTIONAIRE

(1) Potential Application

Type	Quantity Produced/Year
Thick Film Hybrid	(500 present) - (15000 1984)
Thin Film Hybrid	
Monolithic	

(2a) Identify the Characteristics of Your Application

	Thick Film Hybrid	Thin Film Hybrid	Monolithic
High Volume, Few Types			
High Volume, Many Types			
Low Volume, Large No.of Types	✓		
Other (Please Explain)	Large area complex hybrids 50-500/mo		

(2b) Please Characterize Your Typical Thick Film Network Printing Production Run (Quality Printed/Printing Rate)

Very Dense 10 mil lines on 20 mil centers 40% metal coverage (out of max 50%) 10 mil square Vias over 1000 per layer - 6 metal layers per substrate - substrate size 2" x 3" now will be done 2 up (4" x 3") in 1983

(3) Size of Substrates (Minimum and Maximum in Mils)

Minimum 1 x 2

Maximum 3 x 4

(4a) What Are The Number of Circuit Types/Week Do You Visually Inspect?

10 present 300 1984 all complex with average visual taking between 1 and 3 hours

(4b) What is Your Current Visual Inspection Rate? (Circuits/Hour/Operator)

1 to 3 for complex hybrids

(5a) What Percentage of Circuits Produced are Visually Inspected?

100%

(5b) What are Present Levels of Visual Inspection for Each Circuit Type?

100% 883 B Workmanship ; sample to print

(5c) What Level of Visual Inspection Would You Desire if a System Were Available and Cost Effective?

100% Workmanship, 100% to print

(5d) If an Automatic/Semi-Automatic Visual Inspection System were Available, What Inspection Rate Would You Desire?

8 to 10 fold increase

(6) What is Your Present Visual Inspection Cost (Approximate) Per Circuit?

\$25 - \$75 final inspection
50 - 150 in process inspection

(7) What Percentage of Circuit Production Cost does Visual Inspection Represent?

3½-5% final
6-10% in process
10-15% total

(8) Characterize Your Visual Inspection Requirements. List Type of Defects.

in process — printing
a- line width
b- opens, shorts
c- via open, how much
d- voids in dielectric
in process assemble
a- device type
b- orientation
c- correct wiring
final -a Bonds to spec? 883B
b Bonds on target?

(9) Do You Inspect to Criteria Specified in MIL-STD-883?

(a) Method 2010 - Precap Visual for Monolithics yes

(b) Method 2017 - Precap Visual for Hybrids yes

(c) Both of the Above Separately yes

(d) Both 2010 and 2017 at The Same Inspection Point ______

(10) What Amortization Period would be Specified for Investments in Inspection Station Equipment?

3 - 5 years

(11) List Below the Other Requirements You Have That are Not Covered in (1) through (9).

AUTOMATIC VISUAL INSPECTION SYSTEM
MARKET SURVEY QUESTIONAIRE

(1) Potential Application

Type	Quantity Produced/Year
Thick Film Hybrid	1,000,000
Thin Film Hybrid	
Monolithic	

(2a) Identify the Characteristics of Your Application

	Thick Film Hybrid	Thin Film Hybrid	Monolithic
High Volume, Few Types	✓		
High Volume, Many Types			
Low Volume, Large No.of Types			
Other (Please Explain)			

(2b) Please Characterize Your Typical Thick Film Network Printing Production Run (Quality Printed/Printing Rate)

EACH SUBSTRATE HAS ONE CONDUCTOR AND THREE RESISTOR PRINTS.
PRINTING RATES ARE BETWEEN 900 - 1200 PER HOUR.

(3) Size of Substrates (Minimum and Maximum in Mils)

Minimum 500 x 1000
Maximum 2000 x 2000

(4a) What Are The Number of Circuit Types/Week Do You Visually Inspect?

2

Automatic Visual Inspection System
Market Survey Questionaire (Cont.)

(4b) What is Your Current Visual Inspection Rate? (Circuits/Hour/Operator)

60/HR/OP.

(5a) What Percentage of Circuits Produced are Visually Inspected?

10 - 20%

(5b) What are Present Levels of Visual Inspection for Each Circuit Type?

CRITICAL DEFECTS ARE REJECTED AT 0.4% AQL

(5c) What Level of Visual Inspection Would You Desire if a System Were Available and Cost Effective?

0.4% AQL

(5d) If an Automatic/Semi-Automatic Visual Inspection System were Available, What Inspection Rate Would You Desire?

~ 900/HR TO DO 100% INSPECTION TWICE IN THE THICK FILM LINE

(6) What is Your Present Visual Inspection Cost (Approximate) Per Circuit?

DON'T KNOW FOR SURE, ROUGHLY $0.05/CIRCUIT

(7) What Percentage of Circuit Production Cost does Visual Inspection Represent?

BETWEEN 5 TO 10%

(8) Characterize Your Visual Inspection Requirements. List Type of Defects.

CUTS/SHORTS IN CONDUCTORS/PEELING
GROSS MISALIGNMENT.
- CONDUCTOR TO HOLE PATTERN
- RESISTOR TO CONDUCTOR TERMINATION.

VOIDS IN RESISTORS
SPLATTERS/SMEAR OF RESISTIVE MAT'L.

AFTER LASER TRIM.
- REMAINING WIDTH BELOW SPECIFICATION.
- PLUNGE CUT TOO CLOSE TO THE CONDUCTORS.

(9) Do You Inspect to Criteria Specified in MIL-STD-883? NO.

(a) Method 2010 - Precap Visual for Monolithics ______

(b) Method 2017 - Precap Visual for Hybrids ______

(c) Both of the Above Separately ______

(d) Both 2010 and 2017 at The Same Inspection Point ______

(10) What Amortization Period would be Specified for Investments in Inspection Station Equipment?

FIVE TO 10 YEARS

(11) List Below the Other Requirements You Have That are Not Covered in (1) through (9).

AUTOMATIC VISUAL INSPECTION SYSTEM
MARKET SURVEY QUESTIONAIRE

(1) Potential Application

Type	Quantity Produced/Year
Thick Film Hybrid	90,000 (1981) TO 720,000 (1985)
Thin Film Hybrid	NONE
Monolithic	NONE

(2a) Identify the Characteristics of Your Application

	Thick Film Hybrid	Thin Film Hybrid	Monolithic
High Volume, Few Types	✓		
High Volume, Many Types			
Low Volume, Large No.of Types			
Other (Please Explain)			

(2b) Please Characterize Your Typical Thick Film Network Printing Production Run (Quality Printed/Printing Rate)

PROGRAM IS JUST STARTING. 1981 Printing rate assumes 360/hr per machine

(3) Size of Substrates (Minimum and Maximum in Mils)

Minimum 80 mm x 80 mm (3.15")
Maximum 80 mm x 80 mm (3.15")

(4a) What Are The Number of Circuit Types/Week Do You Visually Inspect?

1 First year, probably 8-10 within 5 yrs

(4b) What is Your Current Visual Inspection Rate? (Circuits/Hour/Operator)

(5a) What Percentage of Circuits Produced are Visually Inspected?

(5b) What are Present Levels of Visual Inspection for Each Circuit Type?

(5c) What Level of Visual Inspection Would You Desire if a System Were Available and Cost Effective?

100%

(5d) If an Automatic/Semi-Automatic Visual Inspection System were Available, What Inspection Rate Would You Desire?

900/HR

(6) What is Your Present Visual Inspection Cost (Approximate) Per Circuit?

(7) What Percentage of Circuit Production Cost does Visual Inspection Represent?

(8) Characterize Your Visual Inspection Requirements. List Type of Defects.

Circuit Breaks, shorts between conductors, registration, smears, voids in resistors.

(9) Do You Inspect to Criteria Specified in MIL-STD-883?

(a) Method 2010 - Precap Visual for Monolithics __________

(b) Method 2017 - Precap Visual for Hybrids __________

(c) Both of the Above Separately __________

(d) Both 2010 and 2017 at The Same Inspection Point __________

(10) What Amortization Period would be Specified for Investments in Inspection Station Equipment?

(11) List Below the Other Requirements You Have That are Not Covered in (1) through (9).

AUTOMATIC VISUAL INSPECTION SYSTEM
MARKET SURVEY QUESTIONAIRE

(1) Potential Application

Type	Quantity Produced/Year
Thick Film Hybrid	10K
Thin Film Hybrid	50K
Monolithic	-0-

(2a) Identify the Characteristics of Your Application

	Thick Film Hybrid	Thin Film Hybrid	Monolithic
High Volume, Few Types	✓		
High Volume, Many Types		✓	
Low Volume, Large No.of Types	✓	✓	
Other (Please Explain)			

(2b) Please Characterize Your Typical Thick Film Network Printing Production Run (Quality Printed/Printing Rate)

10 MIL LINES/SPACES ≈ 1K IMAGES/RUN

(3) Size of Substrates (Minimum and Maximum in Mils)

Minimum 250 x 250
Maximum 3000 x 3000

(4a) What Are The Number of Circuit Types/Week Do You Visually Inspect?

50

(4b) What is Your Current Visual Inspection Rate? (Circuits/Hour/Operator)

VARIES A LOT

(5a) What Percentage of Circuits Produced are Visually Inspected?

100%

(5b) What are Present Levels of Visual Inspection for Each Circuit Type?

FAB PRECIRCUIT, MOUNTING, BONDING, PRECAP

(5c) What Level of Visual Inspection Would You Desire if a System Were Available and Cost Effective?

100%

(5d) If an Automatic/Semi-Automatic Visual Inspection System were Available, What Inspection Rate Would You Desire?

500 CKTS/HR. MIN

(6) What is Your Present Visual Inspection Cost (Approximate) Per Circuit?

DON'T KNOW

(7) What Percentage of Circuit Production Cost does Visual Inspection Represent?

DON'T KNOW

(8) Characterize Your Visual Inspection Requirements. List Type of Defects.

CONDUCTOR VOIDS
" SHORTS/BRIDGES
" SMEARS
RESISTOR VOIDS
" BRIDGES

(9) Do You Inspect to Criteria Specified in MIL-STD-883?

(a) Method 2010 - Precap Visual for Monolithics ______

(b) Method 2017 - Precap Visual for Hybrids ______

(c) Both of the Above Separately ______

(d) Both 2010 and 2017 at The Same Inspection Point ✓

(10) What Amortization Period would be Specified for Investments in Inspection Station Equipment?

5 YR. MAX.

(11) List Below the Other Requirements You Have That are Not Covered in (1) through (9).

AUTOMATIC VISUAL INSPECTION SYSTEM
MARKET SURVEY QUESTIONAIRE

(1) Potential Application

Type	Quantity Produced/Year
Thick Film Hybrid	300 K
Thin Film Hybrid	20 K
Monolithic	

(2a) Identify the Characteristics of Your Application

	Thick Film Hybrid	Thin Film Hybrid	Monolithic
High Volume, Few Types			
High Volume, Many Types			✓
Low Volume, Large No.of Types	✓	✓	
Other (Please Explain)			

(2b) Please Characterize Your Typical Thick Film Network Printing Production Run (~~Quality~~ Quantity Printed/Printing Rate)

500 subs / 100-200/hr

(3) Size of Substrates (Minimum and Maximum in Mils)

Minimum 1/c 250 x 250
Maximum 4000 x 4000

(4a) What Are The Number of Circuit Types/Week Do You Visually Inspect?

20

(4b) What is Your Current Visual Inspection Rate? (Circuits/Hour/Operator)

Varies depending on complexity
10/hr to 2/hr

(5a) What Percentage of Circuits Produced are Visually Inspected?

100%

(5b) What are Present Levels of Visual Inspection for Each Circuit Type?

100%

(5c) What Level of Visual Inspection Would You Desire if a System Were Available and Cost Effective?

100%

(5d) If an Automatic/Semi-Automatic Visual Inspection System were Available, What Inspection Rate Would You Desire?

500/hr

(6) What is Your Present Visual Inspection Cost (Approximate) Per Circuit?

?

(7) What Percentage of Circuit Production Cost does Visual Inspection Represent?

≈ 10%

(8) Characterize Your Visual Inspection Requirements. List Type of Defects.

Mil Std 883

(9) Do You Inspect to Criteria Specified in MIL-STD-883?

(a) Method 2010 - Precap Visual for Monolithics ✓

(b) Method 2017 - Precap Visual for Hybrids ✓

(c) Both of the Above Separately ✓

(d) Both 2010 and 2017 at The Same Inspection Point ______

(10) What Amortization Period would be Specified for Investments in Inspection Station Equipment?

5 yrs

(11) List Below the Other Requirements You Have That are Not Covered in (1) through (9).

AUTOMATIC VISUAL INSPECTION SYSTEM
MARKET SURVEY QUESTIONAIRE

(1) Potential Application

Type	Quantity Produced/Year
Thick Film Hybrid	52K
Thin Film Hybrid	100K
Monolithic	

(2a) Identify the Characteristics of Your Application

	Thick Film Hybrid	Thin Film Hybrid	Monolithic
High Volume, Few Types			
High Volume, Many Types			
Low Volume, Large No.of Types	✓	✓	
Other (Please Explain)			

(2b) Please Characterize Your Typical Thick Film Network Printing Production Run (Quality Printed/Printing Rate)

Military Hi-Rel 500-1K per lot 100/hour/print
0.5-10K month
Commercial 5K/lot 350/hour/print 20K/month

(3) Size of Substrates (Minimum and Maximum in Mils)

Minimum 1.2" x 0.625
Maximum 2" x 2"

(4a) What Are The Number of Circuit Types/Week Do You Visually Inspect?

10 types/week - 20 types/week

(4b) What is Your Current Visual Inspection Rate? (Circuits/Hour/Operator)

50 hour including repairs
maximum 2 shifts to support ½ shift bonding day

(5a) What Percentage of Circuits Produced are Visually Inspected?

50% - All Hi-Rel substrates

(5b) What are Present Levels of Visual Inspection for Each Circuit Type?

MIL-STD-883 Method 2010 & 2017 & in-house specs

(5c) What Level of Visual Inspection Would You Desire if a System Were Available and Cost Effective?

Hi-Rel A & B levels
Commercial - Opens & Shorts

(5d) If an Automatic/Semi-Automatic Visual Inspection System were Available, What Inspection Rate Would You Desire?

500 hour

(6) What is Your Present Visual Inspection Cost (Approximate) Per Circuit?

20-30¢

(7) What Percentage of Circuit Production Cost does Visual Inspection Represent?

12%

(8) Characterize Your Visual Inspection Requirements. List Type of Defects.

Thick Film

50% conductor width (small lines/spacings)
50% excess metallization bridging
Soldering problems
Via width & length coverage
Dielectric coverage & alignment - multilayer
Contamination / Staining
Warp factors
Blisters, flaking

Hybrid

2010
2017
in house QC inspections

(9) Do You Inspect to Criteria Specified in MIL-STD-883?

(a) Method 2010 - Precap Visual for Monolithics ✓

(b) Method 2017 - Precap Visual for Hybrids ✓

(c) Both of the Above Separately ✓

(d) Both 2010 and 2017 at The Same Inspection Point ✓

(10) What Amortization Period would be Specified for Investments in Inspection Station Equipment?

Hi Rel Bedford Facility - Labor Supply problem
- 2 years

Commercial - Keene, NH - 3 months

(11) List Below the Other Requirements You Have That are Not Covered in (1) through (9).

Wire bond placement (up to 350 wires/hybrid)
Wire dress (1 & 1.25 mil gold wire)
Laser trim requirements - thin film resistors
epoxy & eutectic coverage (periphery inspection)
gold probe marks

★ Particles ★ Prior to lidding for PIND test
Chip orientation for automatic wire bonding

LME